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Ingot Cogging Mill

AN ENCYCLOPÆDIA OF THE IRON & STEEL INDUSTRY

Compiled
by

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FOREWORD

by

Charles Sykes, C.B.E., F.R.S., D.Sc., Ph.D., D.Met., F.Inst.P.

THE technical background of the Iron and Steel Industry, in common with that of most other undertakings, has increased enormously in scope over the last thirty or forty years, and the amount of technical literature available has reached overwhelming proportions. In addition to this, a terminology unique to the industry itself has been growing up over the years.

The non-specialist in this field of metallurgical practice finds it difficult to keep himself familiar with all that is of interest to him; the specialist may manage to follow the developments in his own subject but only at the expense of becoming more and more out of touch with the subject as a whole.

A work such as the present one is, therefore, very valuable to all concerned with the industry. Whilst it cannot deal at length with any particular subject, and does not attempt to do so, it gives a reference to all the topics met by the author in a search of the relative literature extending over a period of nearly thirty years.

It provides an answer to those who, having found a term in the literature, are at a loss to know the exact meaning; it provides the specialist with information on topics outside his own province; it gives a lead to the student in both the text and the bibliography, which is necessarily very comprehensive; it explains the metallurgist's terminology to the engineer or the sales representative.

This volume should prove to be a valuable addition to all reference libraries and particularly to those used by the Iron and Steel Industry.

C. SYKES

PREFACE

THE purpose of this Encyclopædia is to provide a concise description of the materials, plant, tools and processes used in the Iron and Steel Industry, and in those industries closely allied to it, from the preparation of the ore down to the finished product; and to define the technical terms employed.

The work is intended as a work of reference, not in any sense as a textbook. I would not expect an expert to consult it in his own field (though I firmly believe that it is technically well found); but the specialist might usefully look to it for information on subjects bordering his own—a metallographist, for instance, or a corrosion expert will find in it the full meaning of terms used in pyrometry, or in the steel-melting plant, the rolling mill or the foundry. In particular, it is my hope that the book will prove of value to those smaller firms in the Iron and Steel and Engineering industries which have not yet attained sufficient size to warrant their maintaining a library of their own.

The origins of the Encyclopædia go back to the formation, a few years after the end of the First World War, of a Library and Information Bureau at the Brown-Firth Research Laboratories in Sheffield. These Laboratories exist to serve the interests of the great Sheffield steel-making firm of Thos. Firth and John Brown Ltd., of Firth-Vickers Stainless Steels Ltd., and of the other associated companies of the Group and I was appointed Technical Librarian and Information Officer at the Laboratories in 1927.

From the earliest days of the Library, many enquiries of a technical nature began to be received; and it became obvious that in order to facilitate the answering of these queries, a fairly comprehensive card index was a first essential. Demand created supply; and over the years the index, constantly revised and kept up to date, continued to grow.

A few years ago I was asked to prepare a glossary of technical terms, for distribution by the Sales Promotion Department of the Firth-Brown Group. This appeared to meet a considerable demand and has now gone into its third edition. It was therefore felt that the vastly greater body of information contained in our card index (from which the Glossary represented only a selection) might usefully be made available to a larger circle of readers; and with this in view, a detailed search of the literature was undertaken in order to ensure that the information presented was not only as accurate, but also as comprehensive, as appeared practical.

The present work thus represents a recently revised presentation of material collected over more than a quarter of a century.

Obviously, my work has brought me into constant association not only with the scientific staff of the Laboratories, but also with the technical staff of the Works, many of whom have most generously assisted me with their advice in the production of this Encyclopædia.

In particular, I would wish to acknowledge the encouragement given by the late Dr. W. H. Hatfield, F.R.S., and to express my especial thanks:—

To Dr. Charles Sykes, C.B.E., F.R.S., Managing Director, and the

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To the many friends and colleagues who have so generously placed their specialized knowledge at my disposal, and in particular to Messrs. B. Bagshawe, A.Met., F.I.M., M.Inst.F., A. Barker, B.Sc., A.R.C.S., A.I.M., H. Burden, B.Sc., B.M.Cina, Ph.D., B.Sc., A. H. B. Cross, Ph.D., B.Met., F.I.M., C. Edeleanu, M.A., Ph.D., E. B. Fearn, A.Met., A.I.M., P. Fox, B.Met., A.I.M., N. V. Howard, A. Jacques, B.Met., F. W. Jones, D.Sc., Ph.D., P. Jubb, B.Sc., A. Met., N. B. McGregor, J. A. MacWilliam, M.A. (Eng.), M.I.W., W. H. Malton, J. I. Morley, A.Met., A.I.M., A. L. Pill, F.R.G.S., J. W. Shillito, H. T. Shirley, B.Sc., A.R.C.S., E. Smith, J. E. Truman, A.Met., D. Walker, A.Met., A.I.M., J. K. Walshaw, and R. F. Wright.

And finally to Mesdames E. F. M. Talent, E. Fearn and E. M. Smith, without whose enthusiastic co-operation the completion of the book would have been impossible.

A. K. OSBORNE
The Brown-Firth Research Laboratories

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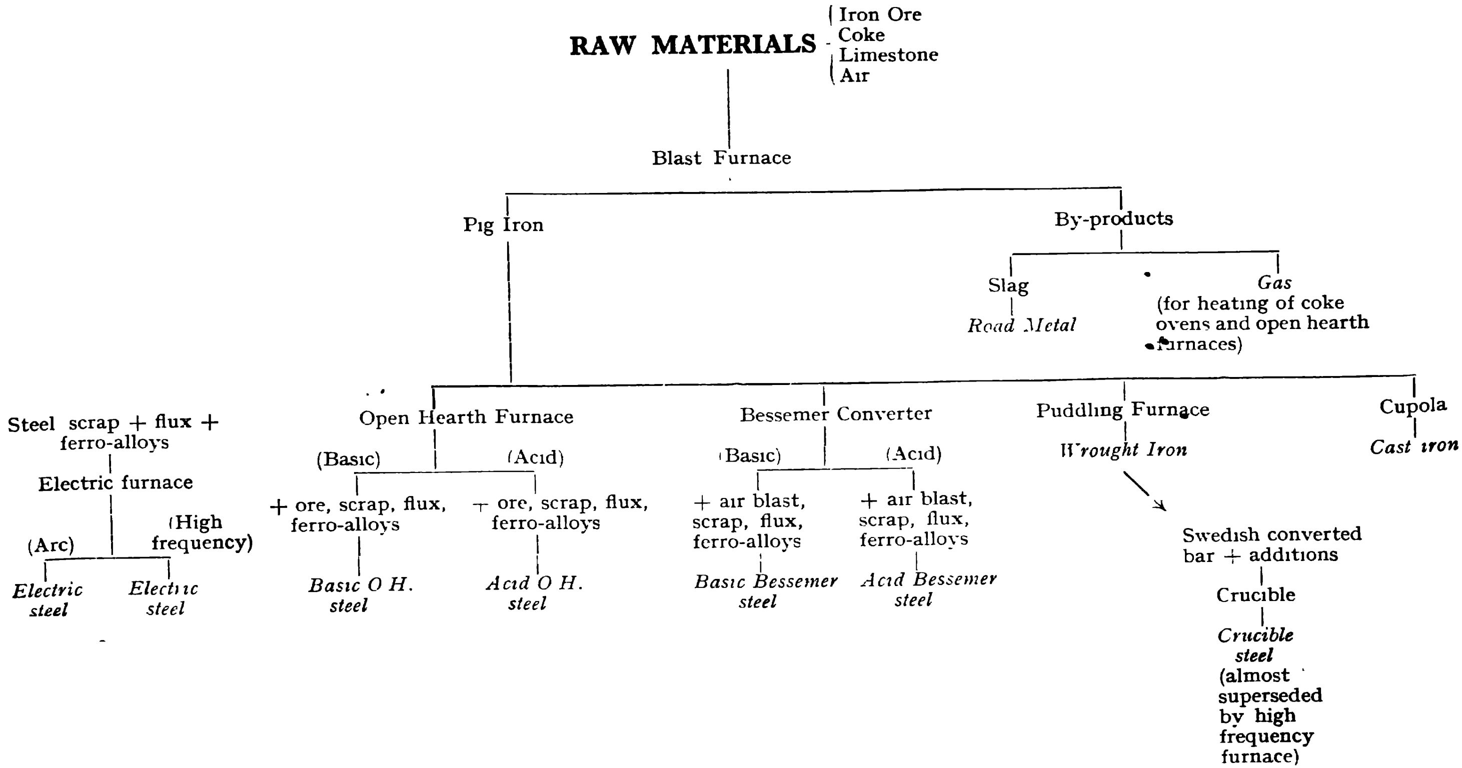

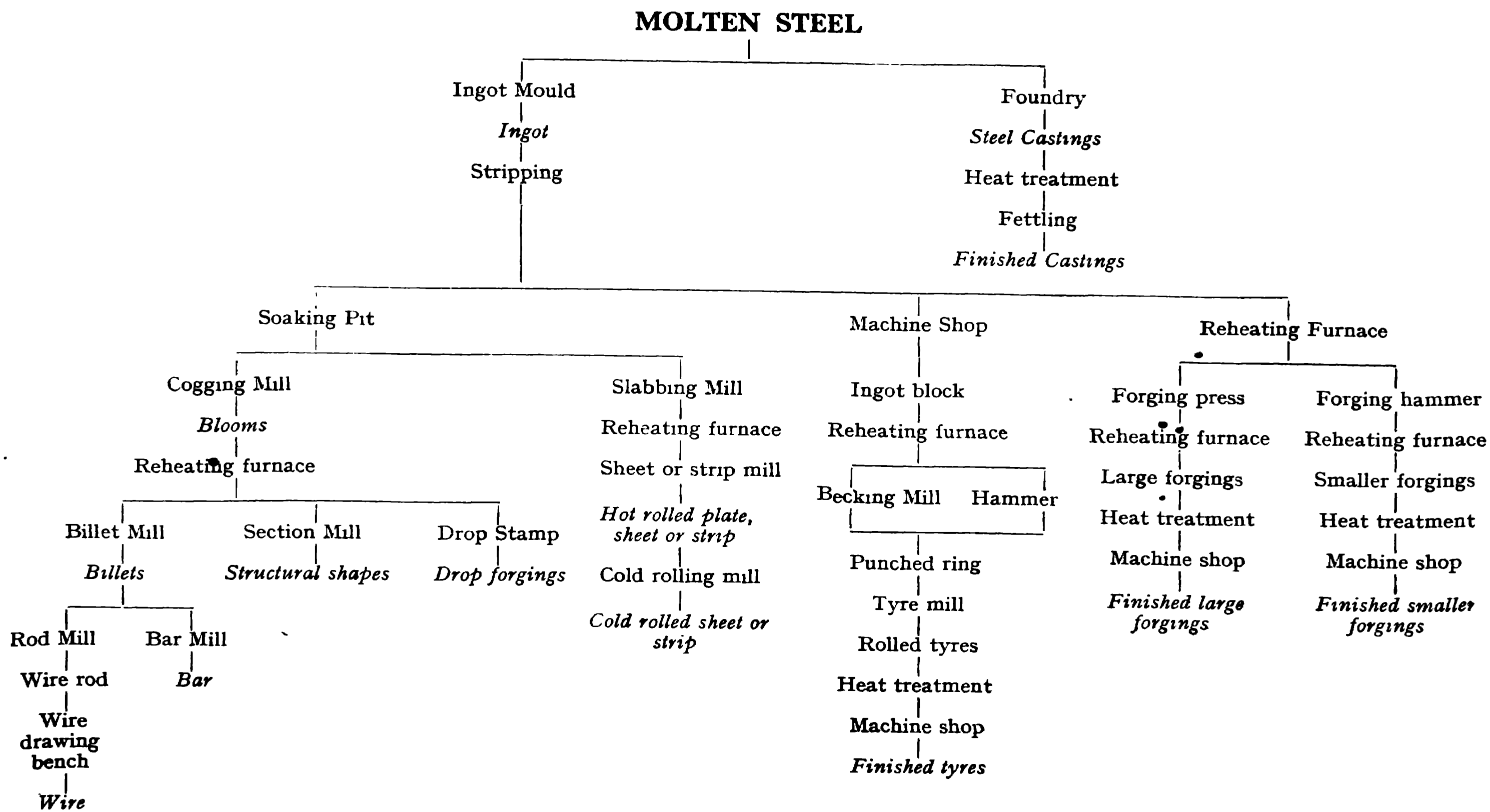
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THE ENCYCLOPÆDIA
(A—Z)

A

A. (*a*) Chemical symbol for *argon*. (*b*) Abbreviation for *ampere*. (*c*) *Annealed*. (*d*) *Arrest* or *critical point*. (See TRANSFORMATION RANGE.)

Å. *Ångström unit.*

A.A.R. *Association of American Railroads.*

A.A.S.M.T.C. Association of American Steel Manufacturers' Technical Committee.

Abampere. The current which, when flowing in a conductor lying at right angles to a field of one line force per square centimetre, causes each centimetre to be acted upon by a force of one dyne. One abampere equals ten amperes.

A.B.B.F. Association of Bronze and Brass Founders.

A.B.C.C. Association of British Chambers of Commerce.

Abel, Sir Frederick Augustus, Bart., G.C.V.O., K.C.B. (1827–1902). Bessemer Gold Medallist 1897. He established the composition of iron carbide as Fe_3C, and also carried out investigations on the erosion of gun barrels.

Abel's Reagent. An aqueous solution containing 10% of chromic acid used in the etching of steel.

A.B.M.A. American Boiler Manufacturers' Association.

A.B.N.M.A. Aircraft Bolt and Nut Manufacturers' Association.

Abnormal Steels. (*a*) Carbon steels which have relatively poor creep properties. This condition of poor creep resistance is usually associated with the method of deoxidation. Thus, steels killed with large amounts of aluminium (e.g. 2 lb. per ton of steel) have creep properties inferior to those killed by silicon additions only, or a silicon addition plus a small amount of aluminium (e.g. up to ½ lb. per ton of steel). (G. 28.) (*b*) Carburizing steels liable to show soft spots after quenching. McQuaid and Ehn observed that such steels, slowly cooled from the carburizing temperature, showed under the microscope a fine grain size, as outlined by the pro-eutectoid cementite envelopes, while the steels of ample hardenability had a coarse grain size. They also noted another difference in structure, namely, more ferrite and a thicker cementite network in the finer grained steels. This last feature they named *abnormality*—unfortunately, perhaps, since it is a function of grain size and connotes nothing in the nature of an abnormality. (B. 6.)

Abnormality. (See ABNORMAL STEELS.)

Abradum. Finely powdered *alumina* used for polishing.

Abraser. A device for assessing the wear resistance of surfaces. The specimen to be tested is rubbed alternately by the flat faces of two weighted abrasive wheels. These wheels revolve in opposite directions through frictional contact with the specimen and exert a combined abrasive, compressive, and twisting action twice in each revolution of the specimen holder. A range of wheels is available to suit different surfaces such as electro-plated coatings, enamel, plastics, leather, and textiles. The wear is determined by the loss in weight at the end of 1000 cycles with a given load on the wheels. (P. 46.)

Abrasion. The wearing away of the surface of a material by the cutting action of solids.

Abrasion Testing. A test usually conducted by measuring the loss of weight per unit surface area of a sample after it has been in moving contact with a standard hardened and finished ground surface for a definite number of strokes and with a definite pressure. The tests may be rolling or sliding in nature, with or without abrasive, and one metal may be tested in contact with itself or another substance. (See ABRASER.)

Abrasive. A substance used to smooth, wear down and polish. The main natural abrasives are diamond, corundum, garnet, diatomite, tripoli, talc, emery, pumice and pumicite, whiting and silica sand. The manufactured abrasives range from some of the hardest materials known, such as silicon carbide, tungsten and boron carbides, to mild compounds as chromic oxide, ferric oxide (rouge), precipitated chalk (whiting), and calcium phosphate. (W. 1.)

Abrasive-Disc Cutter. A machine for cutting metal bars by means of an abrasive disc, with a face revolving at high speed. It is claimed that extremely hard steels can be cut with such machines. (M. 62.)

Abrasive Hardness. Resistance to surface scratching or wear by rubbing or *grinding*.

Abreuvage. Penetration of metal by

capillary action into spaces existing between the grains of sand, which are the natural interstices corresponding to the grain size of the sand or accidental voids of small depth starting from the surface of the core. Abreuvage can be due to physical causes, more or less connected with refractoriness, or mechanical causes. (F. 37.)

A.B.S. American Bureau of Shipping.

Absolute Alcohol. Water-free ethyl alcohol.

Absolute Hardness. This is variously defined as (*a*) the maximum pressure at the centre of the indent of a projection area—when the impressed material has just reached the limit of elastic deformation (H. 47a), and (*b*) as the value obtained by the *strainless indentation method* whereby a preliminary impression is made in the specimen, after which the strain is removed by annealing, the ball again replaced in the original impression and the load applied. As this procedure is repeated the impression becomes progressively larger until it will support the load with nothing more than elastic deformation taking place. The Brinell hardness obtained from this final impression which appears to be about one-third of the original value, is termed the absolute hardness of the specimen. (H. 19a.)

Absolute Temperature. Temperature measured from *absolute zero*, i.e. the temperature reading in °C. plus 273·13° C. or the reading in °F. plus 459·4° F. (See KELVIN TEMPERATURE SCALE.)

Absolute Temperature Scale. (See KELVIN TEMPERATURE SCALE.)

Absolute Zero. (−273·13° C or −459·4° F.) Theoretically that temperature at which molecules of a perfect gas would possess no kinetic energy and its volume becomes zero.

Absorbent. Having the capacity to take up another substance.

Absorber. For X-rays. A sheet of material placed between the source of X-radiation and the place where it is detected or measured. When this sheet contains elements chosen especially to reduce the intensity of X-rays that have undesired wave-lengths, the absorber is usually called a filter. (A. 27.)

Absorption. The taking up of one substance into the interior of another, the material taken up being distributed throughout the body of the *sorbent*.

Absorption Coefficient. For X-rays in a substance. The rate of decrease, per unit distance traversed in a substance, of the natural logarithm of the intensity of a parallel beam; usually written μ. (A. 27.)

Absorption Limit. (See LIMIT.)

Abvolt. The *electromotive* force developed in a conductor cutting magnetic lines of force at the rate of 10^8 lines per second.

A.C. (*a*) *Alternating current.* (*b*) *Air cooled.*

Ac. Chemical symbol for *actinium*.

Ac_{cm}, Ac_1, Ac_3, Ac_4. (See TRANSFORMATION TEMPERATURE.)

Ac_2. (See MAGNETIC CHANGE.)

'AC' (Alternate Condensate) Test. A corrosion test using condensate or dew to produce the corrosive action. It is claimed to be particularly effective, as water in this form is of maximum corrosivity being in intimate contact with the surface of the sample. The test closely simulates actual weathering conditions in areas not affected by salt spray or salt air, and produces in a 4-minute time cycle the weathering action of a full 24 hours of an area where dew is of nightly occurrence. Specimens can be exposed to varying temperatures and humidities, as well as to air carrying desired contaminants in controlled quantities. The apparatus consists of a turntable upon which samples are mounted, and chambers or tunnels through which the specimens mounted on the turntable pass, so that they are exposed to the atmospheric conditions of each chamber. The cool, dry sample passing into the first chamber comes into contact with a stream of warm, humid air, which causes it to become rapidly covered with a film of condensed moisture. The sample then passes to the second chamber, where it encounters a stream of cool, dry air, which rapidly removes the moisture. (L. 41.)

AC 1 Method. A method for surface-hardening gears of carbon and alloy steels of nearly eutectoid composition. The gears are heated in thermal baths to temperatures of 10° to 100° C. above the Ac_1 point of the particular steel. The heating time is chosen so that the gears remain in the heating bath just long enough to allow the temperature of the teeth surfaces to rise above the Ac_1 point, whilst the temperatures of the teeth cores and other massive parts of the gears remain below that point. The heated gears are then quenched in thermal baths at about 200° C. and a hard surface layer is obtained whilst the cores remain soft. The toughness of the cores can be considerably increased by heat treatment before applying the Ac_1 surface hardening. (P. 25.)

Acetylene (C_2H_2). A colourless, poisonous and highly inflammable gas, generated by the action of water on calcium carbide. It is used in the welding and cutting of metals, for illumination, and

as a fuel, in the manufacture of dyes, and many other purposes.

Acetylene Welding. *Fusion welding*, using acetylene and oxygen.

Acheson Furnace. An electric furnace used for the production of *carborundum*. Coke and sand are packed round a central core of coke through which a heavy current is passed. The silica of the sand is reduced and combines with the carbon to form silicon carbide, i.e. carborundum.

Achromatic. The term as applied to a lens signifies that it is so designed that *chromatic aberration* is at a minimum.

A.C.I. (*a*) Alloy Castings Institute. (*b*) American Concrete Institute.

Acicular Iron. A cast iron characterized by the presence of a needle-like form of ferrite in the microstructure. This is produced when the iron is caused to transform in the temperature range between the higher range at which pearlitic structures are produced and the low temperatures at which martensitic structures are formed and is generally known as *bainite*. In the laboratory, by precise control of cooling rates, acicular structures can be produced in unalloyed irons; but in foundry practice, alloying is necessary to control the transformation rates. Molybdenum, supported by varying amounts of nickel, is the essential alloying constituent. These nickel-molybdenum, acicular cast irons exhibit high strength and toughness allied with high machinable hardness. Grade 26 of British Standard 1452 covers irons of this type.

Acicular Powder. A term used in *powder metallurgy*, meaning needle-shaped particles.

Acid. (*a*) A chemical compound containing *hydrogen* which can be replaced by metallic elements and which produces hydrogen ions in solution. It neutralizes *bases* to form salts and is usually characterized by a sour taste and by turning blue litmus red. (*b*) Metallurgically the oxide of a non-metal.

Acid Bessemer Process. (See BESSEMER PROCESS.)

Acid Bottom and Lining. In a melting furnace, the inner bottom and lining composed of materials that have an acid reaction in the melting process—either sand, siliceous rock, *ganister* or silica bricks. (A. 27.)

Acid Brittleness. (*Pickling Brittleness.*) Lack of ductility induced in steel, especially wire or sheet, when it is pickled in dilute acid to remove *scale*, or during *electro-plating*. Commonly attributed to absorption of hydrogen. (See HYDROGEN EMBRITTLEMENT.)

Acid Converter. (See BESSEMER PROCESS.)

Acid Etch. (See MACRO ETCH.)

Acid Lining. A refractory furnace lining consisting essentially of silica, e.g. silica brick, ganister or sand.

Acid Number. (*Acid Value.*) An expression of the amount of free acid in fats, oils, waxes and resins, expressed as the number of milligrams of potassium hydroxide (KOH) required to neutralize one gram of the material being tested.

Acid Open Hearth. (See OPEN HEARTH FURNACE.)

Acid Process. A steelmaking process, which may be carried out in *Bessemer*, *open hearth* or *electric furnaces*, characterized by the fact that the lining of the furnace employed consists essentially of an *acid refractory*, e.g. silica, and that the steel is made under an *acid slag*. Under these conditions, neither sulphur nor phosphorus is removed from the *charge*.

Acid Refractories. Ceramic materials consisting principally of silica and having a high melting point, e.g. silica brick or sand, and *ganister*.

Acid Resistant Steels. (See STAINLESS STEELS.)

Acid Rock. An igneous rock with a preponderant silica content, e.g. granite.

Acid Slag. (See SLAG.)

Acid Steel. A steel made by the *Acid Process*.

Acid Value. (See ACID NUMBER.)

Ackey. An electroplating solution consisting of a mixture of nitric and sulphuric acids.

Acoustic Strain Gauge. An instrument used for the measurement of surface strains produced by both *static* and *dynamic* loading. It consists of a test gauge, a reference gauge and a control set. The note from a vibrating wire in the test gauge is matched against the note from a similar wire vibrating in the reference gauge. The method of measurement is very sensitive and under normal conditions strains of the order of 1×10^{-6} can be recorded. The test gauge may be used in remote positions and controlled from a distance. (J. 13.)

Actinium. (*Ac*). *Atomic weight* 227. *Atomic number* 89. A radioactive element in group III of the periodic system.

Activation Energy. In metallurgical processes, the energy required for initiating or continuing a reaction. It is important in the theoretical analyses of *flow*, *diffusion* and other processes. (A.27.)

Activator. (See CASE-HARDENING MIXTURE.)

Active Mass. (See MASS ACTION LAW.)

Active Mass of a Substance. The number of gram molecular weights per litre in solution, or in gaseous form.

A.D.A. *Aluminium Development Association.*

Adapti Investment Casting Process. A *lost wax process* in which one of three methods of casting may be employed, i.e. *centrifugal casting, vacuum-* or *gravity-pouring.*

Addition Agents. (*a*) (*Addition Elements.*) Alloying elements which may be added either to the charge, to the molten bath or to the ladle. (See also FERRO ALLOYS.) (*b*) Reagent added to a plating bath.

Addition Elements. (See ADDITION AGENTS.)

Adeline Steelmaking Process. A process of producing precision castings of steel or steel alloys, which comprises first forming the steel or steel alloy in molten form by the *alumino-thermic process*, by igniting a mixture of iron ore and aluminium, then running the molten metal into a mould prepared by packing a refractory mould composition round a model made of wax or other comparatively low melting point substance and heating to melt out the wax and consolidate the mould, and finally centrifuging the mould. (A. 5.)

Adhesion. The molecular attraction which tends to hold two bodies together. (K.32.)

Adiabatic. A change of the condition of a body without any exchange of heat with the surroundings, e.g. when steam expands or is compressed without losing heat through the walls of the container.

Adiabatic Calorimeter. A *calorimeter* which theoretically remains unaffected by its surroundings, and neither gains nor loses heat. In one such instrument, the sample under investigation (solid or powder) is enclosed in a tapered copper container along the central axis of which is a heating element. The sample and its container are completely enclosed by a copper radiation jacket which is maintained at the same temperature as the sample by electric heaters; the radiation jacket is, in turn, enclosed in a furnace. The furnace is evacuated or filled with inert gas, as desired. The temperature of the sample and jacket are measured with platinum/platinum–10% rhodium thermocouples, and the temperature difference between the sample and the radiation jacket is indicated by copper/gold palladium alloy thermocouples (the sample container and the radiation jacket act as return leads). (A. 50.)

Admiralty Brass. *Alpha-brass* in which some of the zinc is replaced by tin to increase strength and corrosion-resistance.

Admiralty Gun Metal. Alloys consisting of 87·5% to 88·5% copper, 9·5% to 10·5% tin and 1·5% to 2·5% zinc.

Admos Die Casting Process. A composite casting process in which the steel shell to be lined is completely filled with the molten coating metal, the excess metal being displaced and caused to flow away by the lowering of a punch which acts as a core. (S. 31.)

Adsorption. A surface phenomenon in which one substance is taken up at the solid surface of another, resulting in a change of concentration at the interface. (Cf. ABSORPTION.)

Ae_1, Ae_3, Ae_4, Ae_{cm}. (See TRANSFORMATION TEMPERATURE.)

A.E.C. *Atomic Energy Commission.*

A.E.G. Cupping Test. This test is similar to the *Guillery Cupping test*, except that the distending tool employed, instead of being spherical at the end, is cylindrical with a rounded edge. A typical tool is 40 mm. diameter, with an edge radius of 5 mm.; the tests may be carried out in the Guillery machine. Fracture of the specimen occurs round the edge of the cylinder. The diameter of the dies is 50 mm., as in the Guillery test. (G. 37.)

Aeolotropy. The dependence of the properties of steel sheet upon the direction in which the tests are carried out.

Aeration Cell. (*Oxygen Cell.*) An electrolytic cell, the e.m.f. of which is due to a difference in air (*oxygen*) concentration at one electrode as compared with that at another electrode of the same material.

Aerator. A foundry machine used for cooling and decreasing the density of sand by admixture of air.

A.E.R.E. *Atomic Energy Research Establishment.*

Aeric Acid. An obsolete term for carbon dioxide.

Aero Case Process. A method of *case hardening* in which the activating ingredient is calcium carbide. The salt bath is a mixture of anhydrous sodium and calcium chlorides.

Aerocrete. A substance characterized by its good thermal and sound insulating properties. It is obtained by the interaction of aluminium and an alkali whereby the aluminium is attacked and gas and heat are evolved, so that a foamy porous substance results which is somewhat similar to pumice stone.

Aerograph. A trade name for a device used to spray paint.

Aerometer. An instrument for measuring

the weight and density of air and gases.

Aeronautical Inspection Directorate. (*A.I.D.*) (Ministry of Supply.) Test House, Harefield, Middlesex.

A.E.S. American Electroplaters' Society.

A.F.A. American Foundrymen's Association.

A.F.A. Clay. (See CLAY SUBSTANCE.)

Affinity. (See CHEMICAL AFFINITY.)

A.F.N. Association Française de Normalisation.

After Blow. The final stage in the basic *Bessemer process*, when after the complete removal of the carbon, the blast is continued for some three or four minutes. It is during this period that the majority of the phosphorus is removed.

After Contraction. The permanent linear contraction of a material found after reheating to a specified temperature for a given time, expressed as a percentage of its original length.

After Expansion. The permanent linear expansion of a material found after reheating to a specified temperature for a given time, expressed as a percentage of its original length.

After Flow. The plastic flow in metals which continues after the stress has been removed.

Ag. Chemical symbol for *silver*.

Aga Deep Welding. An *oxy-acetylene welding* technique in which the flame heat is efficiently utilized by keeping the flame well down between the edges to be welded. (G. 69.)

Agate. A natural aggregate of crystalline and colloidal silica. It usually contains about 98% SiO_2 and is coloured by metallic oxide. It is extremely hard and for this reason is used for the manufacture of pestles and mortars and for the knife edges of chemical balances and for the bearings of scientific instruments.

Age Hardening. (See AGEING.)

Ageing. (*a*) (*Age Hardening*). A process causing structural change which may occur gradually in certain metals and alloys at atmospheric temperature (*natural ageing*), or more rapidly at higher temperatures (*artificial ageing*). As a result of ageing, the proof stress, maximum stress and hardness values are increased, with some reduction in ductility. These effects are caused by precipitation from a supersaturated solid solution so that the ageing treatment is usually preceded by a solution treatment at a much higher temperature. The precipitate may be submicroscopic. There is a tendency to apply the term "ageing" to steels; "age hardening" to non-ferrous alloys. Where the ageing is produced by heating at elevated temperatures, i.e. artificial ageing, the effect is often referred to as *precipitation hardening*, whilst the terms *dispersion-* or *structural-hardening* have been used. (*b*) (See MAGNETIC AGEING). (*c*) (See QUENCH AGEING). (*d*) The term when applied to cast iron refers to the practice of allowing the castings to stand for a period of some months with the object of equalizing internal stresses and of minimizing distortion.

Ageing Coefficient Core Loss. The percentage change in the specific core loss resulting from continued heating at 100° C. for 600 hours. The term, in a positive sense, indicates an increase in loss. (A. 28.)

Ageing Index. (See AGEING TEST.)

Ageing Test. The procedure consists of straining a tensile test piece through the *yield point* to 10 per cent *elongation*. The load is noted at this point and the test piece removed for *ageing* at 100° C. for 24 hours. The test piece is then replaced in the *tensile* machine and the load again applied. The load at the new yield point is again noted. The increase in load, if any, is expressed as a percentage of the original load, the result being called the *Ageing Index*. (K. 34.)

Agglomerate. An assembly of powder particles of one or more constituents knitted closely together by settling from a solution or suspension or by pressing or heating to subsintering temperatures. (G. 30.)

Agglomeration. (*Flocculation.*) The gathering together of small particles into larger particles. The term is used in connection with the fineness test for foundry sand.

Aggregate. (*a*) (See METARALS). (*b*) Sand, broken bricks, and stone used together with cement in the production of concrete.

A.G.M.A. American Gear Manufacturers' Association.

$AgNO_3$. Chemical formula for silver nitrate.

Agricola, Georgius.(1494–1555.) Author of "De Re Metallica", the great work on mining and metallurgy, published in 1556, six months after the author's death.

AgO. Chemical formula for silver oxide.

Aguilas Ore. Spanish red haematite.

A.H. Air hardened.

A.I.A. Aircraft Industries Association.

A.I.Ch.E. American Institute of Chemical Engineers.

A.I.D. *Aeronautical Inspection Directorate.*

A.I.E.E. American Institute of Electrical Engineers.

Air Acetylene Welding. A gas welding process in which fusion is obtained by the heat derived from the combustion of acetylene gas in air, no filler rod or pressure being used.

Air Belt. Windbox. (See CUPOLA.)

Air Box. Windbox. (See CUPOLA.)

Air Classification. The separation of powder into particles and size ranges by means of a controlled air stream.

Air Cooled Slag. (See CRUSHED SLAG.)

Air Cooling. (*Air Quenching.*)

Air Cushion. A pneumatic pressure device incorporated in the air operating mechanism of a resistance welder to provide a deceleration of a mechanical motion which may or may not be adjustable.

Air Dried Strength. The strength (*compressive, shear, tensile* or *transverse*) of a sand mixture after being air dried at room temperature. (A. 26.)

Air Furnace. A furnace of the *reverberatory type*, similar to the *puddling* furnace. It was used for melting pig iron for the production of castings and consisted of a fireplace at one end, and a stack at the other. The *hearth* was situated between the two and was usually lined with silica. The roof over the hearth sloped towards the stack The metal was melted by a flame produced by fuel burning at the one end of the furnace, which passed over the hearth to the exit at the other end. Heat was thus reflected from the roof and sides of the furnace.

Air Hardenability Test. (*Post Test.*) The test consists of taking a 6-in. round by 6-in. long slug of 32% nickel-iron alloy, drilling a 0·858-in. diam. hole through its centre, and tapping about 1 in. at each end. The hardenability specimen itself is 7 in. long of which 4 in. of this length (1-in. diam.) extends from the end of the 6-in. slug and the remaining 3 in. (0·856 in. in diam.) reaches into the centre of the slug. Two specimens are inserted, one into each end of the 6-in. round, the assembly is then heated to the hardening temperature, soaked at heat, removed from the furnace, placed on an elevated wire screen, and air-cooled. The specimens are then unscrewed, flats ground on two opposite sides, and hardnesses taken at locations corresponding to definite cooling rates. (P. 37.)

Air-Hardening Steel. (*Self Hardening.*) Strictly, the term refers to a steel which becomes martensitic, i.e. fully hardened, on cooling in air from above its critical point, and does not require rapid quenching in oil or water, but it may also be applied to varying degrees of non-martensitic hardening, e.g. where the steel, although not wholly martensitic, attains adequate hardness on cooling in air. Such steels are produced by the addition of certain alloying elements which lower their critical range on cooling; a typical example contains 0·30% carbon, 1·3% chromium and 4·5% nickel. It should be noted that sufficiently rapid air cooling can be obtained only if the *mass* of the steel does not exceed a certain section which varies according to the composition.

Air Holes. A name sometimes given to *gas holes* but seldom used.

Air Lock. (See SAND BLOW.)

Air Patenting. A method of *patenting* in which the steel is air cooled.

Air Port. The air inlet in an *open-hearth furnace*.

Air Quenching. The cooling of ferrous alloys in air from above the *transformation range*.

Air Receiver. A vessel intended to contain air or inert gas above atmospheric pressure.

Air Test. A method of testing tubes in which they are submerged in water or other liquid and submitted to a specified internal air pressure. Any crack or other unsoundness is shown by the escape of air bubbles.

Airblast. (See SAND BLASTING.)

Airbond. A resinous type of *core binder* which dries on exposure to air.

Airco Process. A method of *flame hardening*.

Aircomatic Welding. This process is characterized by an inert-gas-shielded arc between the workpiece and a consumable electrode consisting of a filler rod through which metal is transferred to the workpiece where it becomes part of the joint. The resultant high intensity heat source permits very rapid welding. (M. 176.)

Aired Bars. Defective *blister steel bars* which have become decarburized, owing to the admission of air in the *cementation process*, and are covered with scale instead of blisters.

Airy Points. The best positions for supporting a bar horizontally at any number of points in order that sagging or bending of the bar should be at a minimum.

A.I.S.E. Association of Iron and Steel Engineers.

A.I.S.I. American Iron and Steel Institute.

Ajax Hultgren Salt Bath Furnace. A heat treatment furnace in which the salts are fused by pairs of closely spaced *electrodes* immersed in the bath itself. A feature of this bath is its automatic stirring and it is claimed that the hardness of the product heated in

this type of furnace is extremely uniform. (D. 10.)

Ajax Wyatt Furnace. An electric *induction furnace* having an iron core. The container is so shaped as to ensure optimum circulation of the charge.

Al. Chemical symbol for *aluminium*.

Alaite. ($V_2O_5.H_2O$.) A vanadium ore.

Alba Crack Detector. A device consisting of an electromagnet with movable poles between which the part for examination is placed. The intensity of magnetization is adjusted by means of a rheostat.

Albond. A kaolinite clay found in Dorset. It is used as a low percentage addition to natural moulding sands.

Alclad. A light alloy of the *duralumin* type coated with high purity aluminium which provides high corrosion resistance.

Aldip Process. A process for coating steel and other ferrous metals with aluminium. Grease, scale and dirt are removed by an alkaline cleaner, an acid pickle, and rinsing. After furnace-drying, the steel is placed for 4 minutes in a bath of preheating salt at temperatures from 690° to 760° C., and then transferred to an aluminium bath, covered by a ½-in. layer of salt flux, for 30 to 60 seconds and then returned while still red hot to the preliminary salt bath from which it is slowly raised. As the Aldip skin cools, it assumes a silvery appearance. Any excess aluminium is removed by air-blasting. (M. 91.)

Alexander Sheet Metal Tester. A machine for making the *Erichsen* test, in which a test piece is clamped between two dies and held so that the metal has play and can flow while a perfect round-end tool is moved forward gradually by the hand-wheel until fracture occurs. The operator constantly observes the image of the test piece in a mirror, and when fracture appears, the depth of the impression is read directly from a micrometer scale. Sheet or strip material up to $\frac{3}{16}$ in. thick can be tested.

Alfameter. (*Alphameter*.) An instrument used to check and measure die cones and die cone angles. It works entirely optically by means of light beams entering the die cone parallel in the direction of the die axis; these beams are then reflected by the polished die walls. (L. 55.)

Al-Fin Process. A method of bonding aluminium to steel and cast iron. The required bond is obtained by what is essentially a casting process. The ferrous part, suitably cleaned, is immersed in a bath of molten aluminium and upon attaining the temperature of the bath is attacked by molten aluminium, an aluminium-rich alloy being formed at the interface. After being thus "tinned" with the aluminium alloy, the part is removed from the bath, placed in a mould, and the aluminium casting alloy poured about it so that the cast metal fuses with the still molten coating. Upon cooling the is work removed from the mould and machined as required. (S. 135.)

Aliquot. A measured proportion of the total volume of a solution.

Alitizing. A process in which steel is heated for 3 hours or longer at 930° to 950° C., embedded in a mixture of alumina 49 parts, 55/45 aluminium-iron alloy 49 parts, ammonium chloride 2 parts. Hydrogen is passed slowly through the tubular furnace during the process.

Alkali. A substance which when dissolved in water, neutralizes acids, turns red litmus blue and yields hydroxyl ions, e.g. caustic soda and caustic potash.

Alkali Metals. Metals of group 1A of the periodic system, including *lithium*, *sodium*, *potassium*, *caesium* and *rubidium*. (A. 27.)

Alkaline Derusting. A process for derusting steel, cast iron and other ferrous alloys, without the application of heat. Heavy contamination of oil should first be removed, but light oil is readily removed in the bath. The parts are then immersed in the derusting solution where they are made the cathode for periods varying from a few seconds to several minutes, depending on current density and condition of the surface. A wide range of current density can be employed, from five to several hundred amperes per square foot. After derusting, the object is clean and bright. Longer treatment does not result in any attack upon the metal being pickled. (M. 114.)

Alkaline Earth. An oxide of one of the *alkaline earth metals*.

Alkaline Earth Metals. Metals of group IIA of the periodic system, including *calcium*, *strontium*, *barium* and *radium*. (A. 27.)

Alkins' Effect. An effect first noted by Alkins, that when certain physical and mechanical properties of cold drawn copper wires are plotted against the percentage reduction of area or some similar function of the amount of cold work imposed on the material, there exists a definite discontinuity in all the curves, indicating that over a certain range of cold working an alteration in the rate of change occurs in the property under consideration. (A. 21.)

Allanite. A mineral containing *cerium* and *lanthanum*.

Allgemeine Elekricitat Gesellschaft Test. (See A.E.G. CUPPING TEST.)

Alligator Squeezer. A tool, having a fixed bottom jaw and a movable top jaw, used in *shingling*.

Alligatoring. (*Fish Mouthing.*) The longitudinal splitting of flat slabs in a plane parallel to the rolled surface. (A. 27.)

All-Mine Pig Iron. Pig iron which has been smelted from iron ore without any addition of scrap.

Allogenic. Originating elsewhere.

Allomeric. Having the same crystalline form but different chemical composition.

Allomorphs. Substances having the same chemical composition but different crystalline forms.

Allotriomorphic. A term applied to a *crystal* which has taken its shape from its surroundings, i.e. a crystal whose normal growth has been restricted, such as one found within masses of metals where mutual interference interrupts growth. Such a crystal, although irregular and *polygonal* in shape, retains its characteristic internal arrangement.

Allotropic. Existing in more than one state.

Allotropy. The property possessed by some elements of existing in two or more states (allotropes), differing widely in properties and each stable within certain limiting conditions of temperature and pressure, e.g. carbon has three allotropic varieties, diamond, graphite and *amorphous* carbon. The allotropy of iron modifies the solubility of carbon, and it is due to this fact that steel can be hardened. (See IRON-IRON CARBIDE DIAGRAM.)

Alloy. (*a*) A substance having metallic properties, consisting of two or more elements, or of metallic and non-metallic elements, which are miscible with each other when molten, and do not separate into distinct layers when solid. Alloys when solid may be composed of *eutectics*, *eutectoids*, *solid solution*, *chemical compounds*, or of aggregates of these components with each other or with pure metal. In the commercial sense, the term "alloy" would also include the case where some separation into distinct layers had occurred. (*b*) In the Mint, the base metal added to the more precious ore.

Alloy Cast Iron. (See CAST IRON.)

Alloy Elements. Chemical elements, other than carbon, and usually metallic, which are deliberately added to steel for the purpose of inducing special properties.

Alloy Powder. A powder, each particle of which is composed of the same alloy of two or more metals. (G. 30.)

Alloy Steel. A steel to which one or more alloying elements have been deliberately added with the object of conferring particular properties upon it. (Cf. CARBON STEEL.)

Almen Gauge. An instrument for measuring the intensity of *shot-peening*. It consists of a dial indicator gauge having four bearing points in fixed positions, accurately spaced, bearing on the unpeened surface of the *Almen test strip*. The dial indicator plunger also bears on the unpeened surface, midway between the four points, and gives the test strip arc height reading. Since intensity is variable, the test strip "arc height" is also variable. The Almen test strip, therefore, provides a means of determining or controlling the intensity applied to a given part. (H. 87.)

Almen Test Strip. A strip of steel, of known quality, and fixed size, when peened on one surface will respond in the form of an arc longitudinally and more or less transversely. The measurement of the test strip curvature or the "arc height" indicates the peen "intensity". By peening this test strip in a manner similar to or exactly like the peening of the part, measurement is obtained by comparison. (H. 87.)

Almeria Ore. A Spanish haematite.

Al_2O_3. Chemical formula for *alumina*.

Alpha Beta Brass. These brasses consist of two solid solution phases, *alpha* and *beta*. When cold, the hard beta crystals give increased *tensile* strength but reduce the *ductility*. When heated, however, the presence of the beta crystals renders the brass plastic over a wide range of temperature, so that brasses containing 39% to 43% of zinc are easily worked by hot rolling, extruding or hot stamping at temperatures from 600° to 800° C.

Alpha Brass. A copper-zinc alloy with a copper content greater than approximately 64%. It is composed of only one solid solution phase, and possesses good tensile strength, combined with considerable ductility when cold. It is suitable for the production of sheet, strip, tube, wire, etc.

Alpha Durometer. A form of *Brinell hardness* tester which can be adapted for use in making comparative measures on the *Brinell*, *Durometer* and *Rockwell* C and B scales. For the Durometer test the indenter is a 120° diamond cone, having a sharp point; for Rockwell or Brinell tests, balls of various sizes and different loads are used.

Alpha Forming Element. An element which when added to steel tends to suppress the *gamma* form.

Alpha Iron. The *allotropic* form of iron,

stable below 910° C., the atoms being arranged in a *body centred cubic space lattice*. It is magnetic below the magnetic change point, which, in pure iron, occurs at 770° C. Above the magnetic change point, it was formerly known as *beta iron*.

Alpha Martensite. A form or stage of *martensite* of somewhat arbitrary distinction, sometimes characterized by its tetragonal crystal structure (cube of iron atoms elongated in one direction by strain from trapped carbon), and probably representing the least developed and most distorted stage in the transformation of *austenite* to martensite at ordinary temperatures. (Z. 4.)

Alpha Particle. A *helium* nucleus—that is, a helium atom which has lost two electrons and has, therefore, a double positive charge. It contains two *protons* and two *neutrons*.

Alpha Radiation. A stream of *alpha particles*.

Alphameter. (See ALFAMETER.)

Alsifer. A ferro alloy containing approximately 20% aluminium, 40% silicon, and 40% iron. It is used in steelmaking for final deoxidation and for grain size control.

Alsithermic Reducing Agent. An alloy composed of 50% aluminium, 35% silicon, 10% iron, 3% titanium, the rest being carbon, calcium, phosphorus, and sulphur. It is claimed that by the use of this alloy it is possible to achieve alumino-thermic and silico-thermic reactions at the same time.

Alternate-Immersion Test. A type of corrosion test in which the specimen is immersed cyclically in the corrosive medium, held for a definite period, and removed at intervals. (A. 27.)

Alternating Current. (*A.C.*) An electric current, the flow of which alternates in direction.

Alternating Stress. The stress produced in a material by forces acting alternately in opposite directions. (See FATIGUE.)

Altiscope. An arrangement of lenses and mirrors or prisms by means of which an object can be observed in spite of intervening objects.

ALTO Steel. Ordinary basic Bessemer steel killed with silicon and aluminium.

Alufer. Steel sheet clad with aluminium or aluminium alloy.

Alumel. A nickel-base alloy containing about 2·5% manganese, 2% aluminium and 1% silicon, used chiefly as a component of thermocouples. (See CHROMEL-ALUMEL COUPLE.)

Alumetier Process. A process for protecting steel against oxidation at high temperatures, in which the steel object is first given a spray-coating of aluminium. It is then covered with a coating, composition not stated, but the purpose of which is to exclude air and at the same time form a flux for the oxides present. Finally, the object is heated to the temperature at which it will be used; the aluminium and iron diffuse into one another, producing dense adherent alloys which resist the high temperatures. The oxides of these alloys have the same coefficient of expansion as the alloys themselves, and in consequence do not become detached when the temperature is raised. This process is claimed to give protection up to about 1100° C. (C. 48.)

Alumina. (Al_2O_3.) Aluminium oxide. A constituent of many of the refractories used in steelmaking. It is found in steel, as a non-metallic impurity, when an excessive amount of aluminium is added as a *deoxidizer*.

Aluminates. *Inclusions* which may occur in steel. They may arise from the refractory lining of the furnace or may be due to the fact that the steel has been treated with aluminium.

Aluminized Steel. Steel sheet coated with aluminium.

Aluminium. (*Al.*) Atomic weight 26·98. Specific gravity 2·70. Melting point 660·1° C. Coefficient of thermal expansion (20° to 100° C.) $23{\cdot}5 \times 10^{-6}$ in./in./°C. Aluminium is a *light metal*, silvery white in colour, possessing considerable malleability and ductility. It is obtained almost entirely from *bauxite*. Owing to its high electrical conductivity, aluminium is used extensively for power transmissions, for cables and bus bars, whilst its high heat conductivity and corrosion-resistance accounts for its wide application in cooking utensils. By alloying with silicon, copper, magnesium, manganese, nickel, and other metals, alloys of widely varying properties are produced and these are used in aircraft construction and other structures where both lightness and adequate mechanical properties are required. Aluminium and its alloys can be produced in the form of sheet, forgings, stampings, castings, etc., and can be joined by rivetting, welding and brazing. Aluminium is added to steel for various reasons and the amount varies according to the rôle it has to play. (*a*) As a deoxidizer it may be added in amounts up to 0·05%. (*b*) For the purpose of inducing fine grain characteristics the aluminium addition varies from 0·04 to 0·10%. (*c*) *Nitriding* steels often contain about 1·5% aluminium for the purpose of promoting the formation of an exceedingly hard surface layer when the

steel is heated in ammonia gas at about 500° C. (*d*) *Heat-resisting steel* may contain up to 15% aluminium for the purpose of promoting resistance to scaling. (*e*) For improved electrical resistance the aluminium content may be of the order of 5%. (*f*) *Permanent magnets* of the precipitation hardening type may contain, in addition to 24% to 30% nickel, from 9% to 13% aluminium.

Aluminium Bomb. A special bomb-shaped mould used for determining the oxygen contents of liquid steel. The method depends upon the determination of the alumina formed by aluminium treatment of steel. (S. 86.)

Aluminium Coating. One method for coating steel strip or wire with aluminium is based on the fact that after the preparation of the steel surface, a film of glycerol is applied and as the strip or wire enters the bath of aluminium through a protective carbon box the glycerol burns quietly, preventing the ingoing strip from oxidizing, and thus avoiding the formation of a skin on the surface.

Aluminium Steel. (See ALUMINIUM.)

Aluminoferrite. (See FERROFERRITE.)

Aluminothermic Process. The production of metals and ferro alloys by reduction of the metal oxides by means of finely divided aluminium powder. The process depends on the fact that when an intimate mixture of metal oxides and aluminium powder is ignited, the heat evolved in the combustion of aluminium to oxide so greatly exceeds the heat absorbed in the decomposition of the oxides of the other metals, that the alumina produced is in the molten state as a fluid slag and allows the metals to separate readily from it. In general, there are two fundamental procedures. In the first, the whole of the mixture forming the smelting charge is introduced into the reaction vessel and ignition takes place at the top of the mass by means of a small amount of the highly-reactive ignition-mixture made up from barium peroxide and aluminium powder. The reaction spreads downwards with violent movement of the fluid slag and metal as the materials react. This reaction may only take 50 to 90 seconds for as much as one ton of raw materials. In the second procedure, most of the unreacted charge is placed in suitable containers near the reaction vessel, only a small proportion of it being placed in the bottom of the latter and then ignited with "ignition powder", or fuse. Once the reaction in the crucible has been proceeding for several seconds, feeding of the remainder of the charge is begun cautiously, being accelerated with the increase in the rate of reaction. It is then possible to continue feeding on to the reacting surface as the vessel fills with liquid metal and slag, until full use has been made of its capacity. In this way, several tons of material can be handled effectively in one operation. (B. 129.)

Aluminizing. A process of spraying *aluminium* on to iron or steel, the object of which is to prevent the formation of scale when the steel is used at temperatures up to 1000° C. The coating consists of three layers: (1) a solid solution of iron and aluminium fused on to the steel; (2) a layer of the alloy $FeAl_3$ with a slight excess of free aluminium; and (3) a thin coating of aluminium oxide. To prevent oxidation of the aluminium after the spraying, the part is subjected to a sealing treatment; this consists of brushing on, or dipping in water-glass, and heating the part to 1010° C. for 10 minutes and cooling in still air. (K. 54.)

Aluminous Ores. Iron ores in which the gangue consists principally of alumina.

Alundum. A trade name for abrasive material produced by fusing bauxite, or alumina, in an electric furnace.

Alzak Process. An electrolytic process in which the surface is first electropolished, then anodized to produce a transparent protective coating of aluminium oxide. (P. 19.)

Am. Chemical symbol for *Americium.*

Amalgam. An alloy of a metal and mercury.

Ambient Air. The surrounding air.

Ambient Temperature. Temperature of surrounding air.

A.M.C.C.W. Association of Manufacturers of Chilled Car Wheels.

Amco Soaking Pit. A recuperative type soaking pit in which the flame enters the combustion chamber through a port in the hearth and the waste gases are removed through spaced outlets situated near the corners of the side walls, passing into the recuperator and thence to the stack. (S. 89.)

American Bloomery. A hearth for the direct production of malleable iron. It consisted of a hearth about 2 ft. wide, 2½ ft. long, about 20 in. deep above the *tuyere* and 12 in. below it. The air was preheated by leading through an iron pipe passing over the hearth. The blast was provided by means of bellows. Charcoal was first placed on the hearth and the blast turned on. Then coarsely pulverized iron ore and charcoal were charged alternately. As the ore was reduced, it collected on the hearth and was formed into a pasty ball containing a considerable amount of slag. When

this ball (or *loup*) had attained the desired size it was withdrawn and hammered into a *bloom*. The process is now obsolete.

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American Societies. (See Appendix V.)

American Westin Process. A method for forming and closing tube ends in which the equipment consists essentially of a welding transformer and a split forming die, to which electrical current is supplied by the transformer. Tubes ranging from $\frac{1}{16}$ to $\frac{3}{8}$ in. wall thickness and $\frac{3}{4}$ to 16 in. diam. are considered to be within practical forming limits. (W. 49.)

Americium. (*Am.*) *Atomic weight* 243. All the known isotopes of this element are radioactive and are formed from other transuranic elements. It may be chemically extracted from the parent *plutonium*. The specific activity which it must possess may be calculated as 3·2 c/gm. The yield of this isotope is good, and already experimental quantities have been prepared.

Ames Portable Hardness Tester. The Rockwell penetration method of testing the hardness of metals is accomplished with the tester by applying pressure to the penetrator by screw action. Tests are made directly in the Rockwell scales, with the penetrator and pressure loads specified in a *Rockwell* conversion chart furnished. Brinell equivalents can be readily estimated. As the large handwheel of the device is turned to increase the pressure, the tester frame is forced open and the lever on the front of the frame is lifted, thereby causing the indicator hand to move around the dial. (M. 147.)

Amianthus. A white silky variety of asbestos.

Amines. Derivatives of ammonia by substitution of one or more hydrogens by an alkyl or aryl group. The primary amines are important in the production of amino-aldehyde plastics.

Ammeter. An instrument bearing a scale, graduated in amperes, for measuring electric current.

Ammonia. (NH_3.) Boiling point −33° C., freezing point −77° C. A colourless, strongly alkaline gas which is easily liquefied. Ammonia gas is readily soluble in water, forming the liquid commonly known as ammonia, i.e. ammonia hydroxide (*Spirits of Hartshorn*). Ammonia, on heating to temperatures above 485° C. tends to dissociate into its component gases, nitrogen and hydrogen. At 650° C., in the presence of an active catalyst, it dissociates completely. With higher dissociation temperatures of 870° to 985° C., and in the presence of a catalyst, dissociation is more rapid, yielding a gas consisting of 75% hydrogen and 25% nitrogen by volume and containing usually less than 0·1% residual free ammonia. Anhydrous ammonia is used for *nitriding* and *dry cyaniding*, as a protective atmosphere both by itself and in conjunction with other gases, and, by dissociation, as a source of hydrogen for *brazing*, and *atomic hydrogen welding*.

Ammonia Carburizing. A term used to designate the simultaneous nitriding and carburizing of steel in a gaseous atmosphere containing both ammonia vapour and carburizing gases. (T. 44.)

Amorphous. Non-crystalline.

Amosite. An asbestos mineral consisting of a magnesium silicate with high iron content.

Ampere. The unit of electric current. The international ampere is the unvarying electric current which when passed through a solution of silver nitrate deposits silver at the rate of ·001118 gm. per second.

Ampere Rule. The direction of a magnetic field about a wire conducting a current is clockwise when observed by looking in the direction of the current.

Ampere Turn Per Inch. A unit of magnetizing force 2·02 times greater than the *oersted*. The magnetic field in a solenoid consisting of n turns per inch of length and carrying i amperes has a strength of n × i ampere turns.

Amperometric Value. A value determined by measurement of the electric current flowing or generated.

Amphiboles. A group of rock forming silicates, of which *hornblende* is one of the best-known varieties.

Ampholyte. An *amphoteric* electrolyte.

Amphoteric. Possessing both acidic and basic properties.

Amplidyne. A cross-field excited direct-current generator in which the field input is much smaller than that of a normal generator; it can, therefore, be applied as an automatic regulator for a wide variety of industrial equipments. (A. 6.)

A.M.S. Aeronautical Materials Specifications. (U.S.A.)

Amsler Abrasion Tester. A wear testing machine in which the specimens under test are in the form of rotating discs in contact with one another. The pressure between the discs may be varied, and they may be tested either in the dry or lubricated condition.

Amsler Ball Print Depth Indicator. An instrument made for use with an indentation hardness tester, e.g. the *Brinell* machine. It has a dial indicator which rests on the test piece by means of three small stationary pins. The measuring spindle of the indicator is in direct contact with the ball indenter which it follows as the indentation proceeds. The reading is taken after the removal of the load, the hardness number being read off from an accompanying table. It should be noted that this value will not necessarily agree with the Brinell number obtained by the normal method from the measurement of the diameter.

Amsler Brinell Machine. An instrument based on the principle of the hydraulic ram and operated by a screw-operated hand pump, avoiding pulsations. The load is weighed by a pendulum, which can be varied to give four ranges of pressure, namely, 500, 1000, 3000 and 5000 kg. Further, a smaller ram can be fitted coaxially with the main ram to give a range of 50 kg. (H. 9.)

Amsler Cold Bend Testing Machine. A machine of 70-ton capacity designed exclusively for bending cylindrical and flat bars around a cylinder and then closing the V-bend until the shanks meet. The machine is of the hydraulic type. The base encloses the electrically driven pump for supplying the pressure oil, the control mechanism and the hydraulic pressure system. The latter consists of a cylinder and ram which are precision ground and lapped to produce a practically frictionless sliding fit of adequate oil tightness. No packing is used.

Amsler Cupping Tester. A machine which can be used for both *Erichsen* and *Persoz* ductility tests. The top die is lowered by means of the handle to clamp the specimen and to set the clearance between specimen and die (0·05 mm.). The thickness of the specimen is measured and read on the engraved scale at the top of the die-holder. A punch is driven against the specimen, which is in the form of sheet, by oil pressure. A gauge indicates the force applied by the punch and is equipped with a maximum force pointer. Depth of penetration is indicated by a vernier-scale in front of the machine. (F. 19.)

Amsler Impact Machine. A pendulum type of machine having a striking energy of 30 kgm. and a striking velocity of 4·95 m. per second. (B. 100.)

Amsler Laffon Hardness Tester. An instrument using a 90° cone as indenter which penetrates into the surface of the material. A constant depth of impression is taken as the standard.

Amsler Recording Extensometer. An instrument giving an enlarged scale of the *stress-strain* diagram.

Amsler Tensile Machine. A *tensile* testing machine operated by oil pressure. A *dynamometer* measures the load applied to the test piece. The machine can be adapted for *compression*, *bending* and *shear* tests.

Amsler Torsion Machine. A machine in which the load is measured by means of a pendulum. When the test bar is in position, the torque applied rotates the pendulum until its static moment balances the applied torque. The inclination of the pendulum is transmitted to the spindle of a pointer which is indicated on the dial of the machine.

Amsler Vibrophore. A high-frequency *fatigue testing machine* of the electronic powered resonance type, capable of applying alternating loads up to ± 2 tons with a superimposed static load of up to 1 ton in tension or compression. The working speed is high and can be selected to fall within the limits of 2,400–8,000 cycles per minute. It is designed for use on cylindrical metal specimens in tension and compression, but can be adapted to transverse shear and torsion fatigue tests with the aid of additional gripping devices. (M. 127.)

Amsler Vickers Hardness Testing Machine. A pyramidal indenter method in which the diagonals of the impression are measured. Direct dead weight loading is used without the interposition of a lever. (W. 53.)

Amsler Wire Testing Machine. In this machine the upper gripping head is suspended from a lever attached to the inner end of a pendulum spindle. The inclination of the pendulum, which is a measure of the load, is transmitted to a pointer moving over a graduated dial.

Anaerobic. Free of air or uncombined oxygen.

Analysis Line. (*Element Line.*) (*Impurity Line.*) In *spectrographic analysis*, the particular spectral line utilized in the determination of the concentration of an element.

Anatase. A mineral consisting essentially of titanium oxide (TiO_2).

Anchor. An appliance used to hold *cores* in position in the mould.

Anchor Testing Machine. A machine, manufactured by Avery's, for the testing of cables and anchors. It has a capacity of 750 tons and its overall dimensions are: length 178 ft. 6 in.; width 21 ft.; height 17 ft. (I. 46.)

Anchorite. A zinc-iron phosphate coating for iron or steel.

Anchorite 100. An accelerated phosphate treatment which changes the surface of ferrous metals into a combination of metallic phosphates which form an integral part of their outer layer. This microcrystalline surface is highly corrosion-resistant and holds paint tenaciously to the metal. The method is readily adaptable to production-line work, and can be used economically and speedily to prepare a variety of metals for organic finishing.

Andalusite. A mineral with the essential theoretical composition $Al_2O_3.SiO_2$. It has a *specific gravity* of about 2·67 and a hardness varying from 5 to 6 on *Moh's scale*.

Andreasen Pipette. A sedimentation apparatus, for the determination of particle size, consisting of a large glass cylinder to which is joined a 10-millilitre pipette with stem extending to a fixed level in the cylinder. A homogeneous suspension of powder in a liquid is allowed to settle, and samples are withdrawn through the pipette at a predetermined schedule calculated from *Stokes' law* data. The samples are evaporated to dryness and weighed. Particle-size distribution may be calculated from the weights of the residues.

Anelastic. (*Elastic After Effect.*) A term introduced to describe strains which are neither elastic, because they do not obey *Hooke's law*, nor plastic because they leave no *permanent set*. Such strains are responsible for many effects, as for example, damping, elastic after effect, mechanical hysteresis, and stress relaxation. (Z. 10.)

Angle Beam Transmission Inspection. A testing technique employing high-frequency supersonic waves entering the welded part at an angle. It is a modification of the *Sperry Supersonic Reflectoscope* technique, and can be applied to the inspection of welds in plate, thin sheets, or sections where shape or contour is more or less uniform, and also to the inspection of internal defects. It is applicable to both ferrous and light metals. (W. 23.)

Angle Bend. (See BEND TEST.)

Angle Iron. Mild steel bar rolled to the cross section of the letter L. It is widely used for light structural work.

Angle Joint. A weld joint where the parts joined form an angle less than 180° with one another.

Angle of Bite. (*Angle of Nip.*) (*Friction Angle.*) In the rolling of sheet or strip, the maximum angle subtended by the strip or stock at entry at which the rolls will grip the strip and pull it forward into the roll gap. At any angle greater than the angle of bite, the rolls will skid on the strip and will not pull it into and through the mill, unless the front end of the strip is tapered off, or an external force is applied to push the strip into the rolls. With the normal square-cornered front end to the strip, the angle of bite is equal to the friction angle—that is the angle whose tangent is equal to the coefficient of friction between the roll and strip. (F.22.)

Angle of Entry. In the rolling of sheet or strip, the angle at the roll centre subtended by the strip at the point of entry, the angle being measured from the plane through the roll axes. (F. 22.)

Angle of Nip. (See ANGLE OF BITE.)

Angle of Rake. (See RAKE.)

Angle Testing. A method of *ultrasonic testing* using shear waves introduced from the surface of the material at approximately 45°. The waves do not reach the flaw directly but do so after a number of internal reflections from both surfaces of the material. Thus, the wave front parallel to the surface is propagated more slowly, and this has the effect of decreasing the wavelength and making the instrument more sensitive. Angle testing is used, not only for flat surfaces, but also for pipes and tubes. (F. 44.)

Anglo American Council on Productivity, 21 Tothill Street, London, S.W.1.

Ångström Unit. (*Å.*) The unit employed for expressing wavelengths of light, ultra-violet radiations and X-rays. It equals 10^{-8} cm.

Angus Smith Solution. A proprietary composition comprising a coal tar base used as a protective coating for tubes. It is applied hot, usually by dipping.

Anhydride. An oxide which, when combined with water, gives an acid.

Anhydrous. A term meaning without water, and usually applied to oxides, salts and minerals in which no *water of crystallization* is present.

Anion. In an electrolytic cell the ion which carries the negative charge against the direction of the current and delivers it at the anode. The term was invented by Michael Faraday.

Anisotropic. A term relating to crystals in which the physical properties vary in different directions.

Anisotropic Magnets. Magnets in which

the *B/Hmax.*, *remanence Br*, and *coercive force Hc*, in one direction, exceed the corresponding values in other directions.

Anisotropy. A term indicating variation in properties in different directions, e.g. in a steel sheet.

Anisotropy Energy. (*Magnetocrystalline Energy.*) The excess energy required to magnetize a crystal to saturation in the hard direction. The anisotropy energy of a ferromagnetic crystal acts in such a way that the magnetization tends to be directed along certain definite crystallographic axes which, accordingly, are called "directions of easy magnetization", while the directions along which it is most difficult to magnetize the crystal are called *hard directions*. Often considerable energy is required to magnetize a crystal to saturation in a hard direction, referred to the lower energy required to saturate along a direction of easy magnetization. (K. 28.)

Ankerite. A mineral containing the carbonates of calcium, magnesium, iron and, in small quantities, manganese.

Annealed-in-Process Wire. This material is dry drawn and annealed at an intermediate stage between rod size and finished size, in order to produce a softer wire of fairly uniform temper. It is important to use this grade where bright wire would be too stiff or too hard for a given forming operation. (T. 32.)

Annealing. Heating steel and holding it at a suitable temperature followed by cooling at a suitable rate, with the object of improving softness, *machinability* and *coldworking* properties or of removing *stresses* and obtaining a desired structure. The annealing temperature is generally about 55° C. above the upper limit of the critical temperature range, and the time of holding is usually not less than 1 hour for each inch of section of the heaviest objects being treated. The objects being treated are ordinarily allowed to cool slowly in the furnace. They may, however, be removed from the furnace, and cooled in some medium, e.g. under ashes, which will prolong the time of cooling as compared to unrestricted cooling in the air. Where possible the more specific terms should be used. Certain specific heat treatments covered by the term annealing are:

Black annealing
Blue annealing
Box annealing
Bright annealing
Cyclic annealing
Dead annealing
Flame annealing
Full annealing
Galvannealing
Graphitizing
Homogenizing
Intermediate annealing
Inverse annealing
Isothermal annealing
Malleablizing
Process annealing
Subcritical annealing

Definitions of the above terms are given in alphabetical sequence. (See Plate VIII(c)).

Annealing Carbon. (*Temper Carbon.*) The apparently *amorphous* finely divided carbon, having some graphitic properties, which separates from white cast iron, and from certain steels during prolonged *annealing*.

Annealing Pots. Iron containers in which *castings* are packed for protection against the furnace atmosphere during the annealing process.

Annealing Twin Bands. (See TWINNING.)

Anode. The positive electrode in an electrolytic cell, i.e. the electrode through which a direct current enters a liquid or gas. It is the electrode at which oxidation occurs and in corrosion processes it is usually the electrode that has the greater tendency to go into solution. Typical anodic processes are anions giving up electrons; metal atoms becoming ions in solution or forming an insoluble compound of the metal; and the oxidation of an element or group of elements from a lower to a higher valence.

Anode Corrosion Efficiency. The ratio of the actual corrosion of an anode to the theoretical corrosion calculated from the quantity of electricity which has passed.

Anode Drop. A term used in welding for the drop in voltage between the nearest point of the arc stream and the positive electrode.

Anode Effect. The sudden drop in current in an electrolytic process caused by the formation of a gaseous film over the surface of the *anode*.

Anode Mud. (See *Anode Slime.*)

Anode Slime. (*Anode Mud.*) The residue which adheres to, or drops from, the anode in electrolytic refining processes.

Anodic. The term given to that metal or alloy in an electrochemical cell which has the lower potential.

Anodic Coating. A coating or film of a metal compound, usually oxide, formed on metals by an *electrolytic oxidation* treatment. (See ANODIC TREATMENT.)

Anodic Etching. A method used in the treatment of metals prior to electrodeposition in which they are made the *anode* in an *electrolyte* at a suitable current density. Anodic etching is also

used for the etching of samples for metallographic examination.

Anodic Oxidation. (See ANODIZING.)

Anodic Pickling. (See ANODIC TREATMENT.)

Anodic Polarization. That portion of the polarization of a cell which occurs at the *anode*.

Anodic Treatment. A method of treatment in which the specimen or work is made the anode in a suitable *electrolyte* and an inert metal is used as cathode and a potential is applied. The effect of such a treatment depends on the material being treated. In the case of aluminium and its alloys the terms anodic treatment and *anodizing* are synonymous, but with, for example, stainless steel, the result of the treatment is to clean or polish the work, when the process is frequently referred to as *electrobrightening*, or *anodic pickling*.

Anodizing. (*Anodic Oxidation.*) A process of coating aluminium or aluminium alloys with a layer consisting essentially of aluminium oxide. The aluminium is made the anode in an electrolytic cell containing dilute chromic, sulphuric, or oxalic acid. The cathode may consist of *lead*, *iron* or *carbon*, according to the electrolyte used. *Oxygen* is generated at the anode and attacks the aluminium, giving rise to a tenacious corrosion-resistant film. The film is somewhat porous, and it is usually "sealed" by means of lanoline dissolved in spirit. If desired, the anodized surface can be coloured with various aniline dyes before sealing. (B. 93.)

Anolyte. That portion of the electrolyte which surrounds the anode and is changed in chemical composition or concentration by reactions taking place at the anode.

Anorthic Crystals. Crystals possessing no plane or axes of symmetry.

Antiferromagnetic Materials. Materials in which the interaction between adjacent ions is negative so that adjacent regions are oppositely magnetized with the result that the magnetic moment of the material as a whole is zero.

Antifouling Paints. Paints of anticorrosive composition for the painting of the bottoms of ships and protection of steel for underwater service. Such paints may vary considerably in composition; some contain metallic copper or cuprous oxide as a toxic, whilst others contain lead or lead salts.

Antifriction Metals. (See WHITE METALS, BEARING METALS.)

Antimony. (*Sb.*) *Atomic weight* 121·76. *Specific gravity* 6·62. *Melting point* 630·5° C. A bluish-white metal with coarsely laminar or granular structure. It is extremely brittle and is neither *malleable* nor *ductile*, and is used only in the alloyed form where it imparts hardness and a smooth finish to soft metal alloys. The fact that both antimony and its alloys expand on solidification, thus reproducing the fine details of the mould, renders it valuable for type metal. It is a constituent of *Britannia metal* and several other non-ferrous alloys. It has been found that steels with 0·17% of carbon and up to 0·69% of antimony can be hot-forged and rolled. Higher rolling temperatures are necessary above 0·55% of antimony. Red-shortness occurs in steels containing more than 0·69% of antimony, and a 1·45% antimony steel cannot be hot-worked without disintegration. Antimony has an inappreciable strengthening effect on the tensile properties of steel, 0·69% raising the maximum stress value by only 2 tons per sq. in., while the ductility and impact values are decreased. Higher antimony steels have little tensile strength and are seriously embrittled. (J. 23.)

Antimony Plating. The coating of mild steel by electrolytically deposited antimony, the surface to be coated having first been roughened by mechanical means. One method of electrodeposition uses antimony trifluoride, ammonium fluoride and ammonium hydroxide in the bath in aqueous solution with a hydroxide ion concentration somewhat below that necessary for precipitation. With normal current densities, a 0·001-in. coating is produced in about 30 minutes. Antimony coatings take a high polish and give silver-like surfaces of reflectivity higher than that of chromium and provide excellent protection against atmospheric corrosion. The metal is unsuitable for use in food containers. Its melting point, 630° C., precludes its use at very high temperatures. (B. 83.)

Anti-Piping Compounds. Substances used to delay freezing of molten steel in the *feeder head*. The chemical compositions of the different proprietary brands vary considerably, but, in general, they consist essentially of mixtures of carbonaceous matter and irreducible oxides. When placed on the surface of the molten steel, the carbon and any other elements present slowly oxidize, thus generating heat, whilst the non-metallic matter in the powder remains as a residue which serves to insulate the molten metal beneath. (G. 49.)

Anvil. (*a*) A block of iron, sometimes faced with hard steel, on which work is supported during forging. The *blacksmith's anvil* has at one end a pointed

beak, i.e. the *beak-*, *beck-* or *bick-iron* or *beckern*, on which bends are shaped. On the top face, at the other end of the anvil, is a square hole which holds the shaping tool required for the work in hand. (*b*) Base of the forging hammer. The power forging hammer has a suitable groove or slot into which the bottom forging die can be fastened by means of tapered keys.

Anvil Cap. (See Sow-Block.)

Anvil Effect. In indentation hardness testing, a local bulging produced on the side of the specimen opposite to that on which the impression has been made. Such bulging leads to false hardness values and occurs when the specimen is too thin for the type of test applied.

Apertometer. An optical arrangement for measuring the numerical and angular aperture of a lens, especially of a microscope objective.

Aphengoscope. A modification of the magic lantern, for exhibiting opaque objects.

A.P.I. American Petroleum Institute.

Aplataer Process. A method of hot galvanizing in which the greater part of the bath is filled with molten lead on which floats a patented dividing liquid, which, in turn, supports a layer of pure zinc only a few inches deep. The part of the bath surrounding the zinc is protected by a special lining so that the zinc cannot come into contact with the iron of the bath. The different metals do not mix in any way during the galvanizing process. The articles to be galvanized are first pickled in the normal way, rinsed in water, and then dipped quickly in a hot bath of lye (salt solution), on leaving which they are covered with a thin crystalline film of salts which dries of its own accord. As this salt film is very resistant to heat, it is advisable to preheat the articles in an oven before galvanizing. They are then placed in the lead bath (450° C.) whereupon the salt film is removed by the lead without the formation of any lead coating and the iron or steel surface is quickly galvanized on coming in contact with the zinc. (S. 47.)

A.P.L.E. Association of Public Lighting Engineers.

A.P.M.A. Annealing Pot Makers' Association.

Apold-Fleissner Process. A method of roasting carbonate iron ore in a shaft furnace. The ore sinks continuously down the furnace while a current of hot air or flue gas, with a low carbon dioxide content, is passed through the body of the ore and a current of cold air is passed upwards through the lower part of the shaft, this part acting as a cooling chamber for the ore and as a preheating flue for the air, which rapidly oxidizes the ferrous oxide in the upper regions of the furnace. The quantity and temperature of the hot gases and cold air are carefully regulated, so as to keep the carbon dioxide content of the flue gas at a minimum, and thereby to ensure thorough roasting of the ore at the lowest possible temperature. A furnace roasting 200 to 450 tons per day requires about 160,000 to 200,000 kg.-cal. per ton, giving a heat efficiency of 73 per cent. (B. 80.)

Apophorometer. An instrument enabling sublimates obtained from substances at high temperatures to be collected in their entirety and weighed.

Apparent Density. (See Density.)

APPITA. Australian Pulp and Paper Industries Technical Association.

Aqua Fortis. Concentrated nitric acid.

Aqua Regia. A mixture of one volume of nitric acid with three volumes of hydrochloric acid. It has been used as an etchant for stainless steel but has to be used with care on account of its rapid action. A solution of aqua regia in glycerine, i.e. 20 ml. nitric acid, 40 ml. hydrochloric acid and 60 ml. glycerine by volume has been used for etching iron-chromium alloys and for austenitic chromium nickel steels.

Aquadag. A proprietary name for a suspension of colloidal graphite, in water, used as a wire-drawing lubricant, particularly in the drawing of tungsten.

Aquelco. A method of cathodic protection developed for use in boilers and cooling systems. In this apparatus one electrode is made of special alloy which when polarized disintegrates and liberates sodium dichromate, sodium aluminate being liberated at the other electrode. Alkali may be added to combine with substances liberated from the electrodes; the compounds thus formed precipitate materials liable to form scale. (M. 80.)

A.R.A. Aerial Ropeways Association.

Araldite. A bonding resin, which is pasty at about 90° C. and liquid at 120° C. It is claimed that it enables an intimate and integral bonding of metals, in particular light alloys or structural steels, merely by thermal setting at +200° C. for one hour, without the application of pressure to the pieces joined, provided that they are immovably held in place. (S. 50.)

Arbitration Bar. A bar 1½ in. in diameter by 15 in. long, cast in a thoroughly dried sand mould, used for testing the quality of cast iron. The bar is submitted to a *transverse test*, the supports

being 12 in. apart. The load is applied in the middle and the deflection at rupture is determined.

Arborescent Powder. (See DENDRITIC POWDER.)

Arbor. (*a*) A metal shape used in supporting a *sand core*. (*b*) Central portion of a composite roll. (*c*) The internal bore of the sleeve of a cutting or grinding machine which receives the spindle.

Ar_{cm}, Ar_1, Ar_3, Ar_4. (See TRANSFORMATION TEMPERATURE.)

Ar_2. (See MAGNETIC CHANGE.)

Arc Blow. The effect of magnetic fields round the arc in *submerged arc welding*.

Arc Brazing. A *brazing* process in which the heat is derived from an electric arc struck between the base metal and an *electrode* or between two electrodes. This method is generally confined to non-ferrous metals. (C. 15.)

Arc Crater. (See CRATER.)

Arc Furnace. An *electric furnace* in which an arc, struck between the carbon or graphite electrodes and the furnace *charge*, is used to produce the heat required to melt metals in a confined space. In the *indirect arc furnace* the arc is formed between the electrodes, projecting, for example, from opposite walls of the furnace, and the charge on the bed of the furnace is heated by radiation from the arc formed above it.

Arc Line. In *spectrographic analysis*, an arc line is a spectral line produced by radiation from atoms in the neutral state. Of present conventions for indicating the neutral atom, it is recommended that the Roman numeral I be written after the element symbol, e.g. Fe I.

Arc of Contact. The arc on the roll surface which is in contact with the strip being rolled. It is the roll arc between the points of entry and exit. (F. 22.)

Arc Process. (See ELECTRIC STEEL.)

Arc-Stream Voltage. The voltage drop along the arc stream. (See also OPEN CIRCUIT VOLTAGE, TRUE ARC and WELDING ARC.)

Arc Voltage. The total voltage across an electric arc.

Arc Weld Surfacing. (*a*) Building up of metal surfaces with deposits similar to the parent metal, with the object of rectifying dimensions. (*b*) The deposition of an alloy of another type on to the original surface with the object of producing a surface having special properties, e.g. *hard surfacing*.

Arc Welding. Fusion welding in which the heat is derived from an electric arc formed either between the *parent metal* and the electrode or between the two electrodes.

Arcair Torch. A fettling tool consisting of a torch which has a carbon electrode with air ducts running parallel to it. It is claimed that compared with the pneumatic chisel, the Arcair torch will cut out a defect at a given depth in much less time and that the resulting groove is narrower. (C. 9.)

Arcogene Welding. A process combining the *autogenous* and *arc welding* processes. A blow-pipe of the usual form is used, but at the same time an arc is struck between the work and the coated electrode. The heat is more concentrated than in the autogenous welding process, and the cooling off is slower than in arc welding, and the elongation of the weld is correspondingly greater. (M. 177.)

Arcronograph. An instrument, developed by the U.S. Naval Engineering Station at Annopolis, for evaluating arc stability.

A.R.D. Armament Research Department, Woolwich.

A.R.D. Magnetic Thickness Tester. An instrument for the non-destructive determination of the thickness of electro-deposited coatings on steel. It consists of a pivoted beam which carries a permanent bar-magnet of circular section at one end and a weight free to move along the other arm, which is arbitrarily divided into suitable units. The instrument is small enough to be carried about easily. (S. 91.)

A.R.D. Process. A development of the *precision casting* process which uses plastic patterns produced in automatic injection machines. (C. 21.)

Ardelt Process. A combined ramming and centrifugal process for the production of pressure socket pipes. Cylindrical moulding boxes are carried vertically on a rotating stand; a pattern is inserted and is rammed up with sand, the mould being rotated about its axis. The pattern is withdrawn, and the mould is blacked and dried. The mould has then travelled through half a revolution round the rotating stand, and it is lifted off and laid horizontally in the centrifugal casting machine. After casting, the pipe is pushed out, and the moulding box is returned to the rotating stand, being freed from sand and cleaned ready for moulding again. Socket cores are prepared in the usual way. (A. 47.)

Ardennite. A vanadium ore consisting essentially of $8MnO_4.Al_2O_3.V_2O_5.8SiO_2.5H_2O$.

A.R.E. Aeronautical Research Establishment.

A.R.E.A. American Railway Engineering Association.

A.R.E. Smoothing Process. A chemical method of polishing steel. It employs

a solution whose standard formula is: oxalic acid (crystals) 25 gm/l., hydrogen peroxide 13 gm./l., sulphuric acid 0·1 gm./l. Provided that these proportions are maintained, the solution may be concentrated, even to the point of saturation with oxalic acid, but stronger solutions tend to produce local furrowing of the steel and to decompose more readily than the relatively dilute standard solution. The solution is used at room temperature, for about 30 to 60 minutes. It is claimed that steel smoothed in this way shows an increased resistance to rusting under light corrosive conditions. (M. 78a.)

Arfwedson. (1792–1841.) The Swedish discoverer of lithium (1817).

Argillaceous Ores. Iron ores in which the gangue is mainly clay.

Argon. (*A.*) *Atomic weight* 39·944. An inert gas, existing to the extent of 0·8% in air, from which it is prepared by liquefaction. It is used for gas-filled electric lamps and in *Argon Arc* and *Argonaut welding*.

Argon Arc Furnace. The furnace body is an upright cylinder which can be made vacuum-tight and is fitted with two or more windows through which the progress of melting can be observed. A tungsten electrode supported by flexible bellows is passed through the roof; the base is a relatively thin copper dish, something like a saucer in shape, which is water-cooled from below and constitutes the melting hearth of the furnace. In operation, the charge is placed on the furnace hearth, and the chamber, after evacuation, is filled with *argon*. An arc is then struck between the tungsten electrode and the charge, and in a very short time a molten pool is produced which rests—held together by surface tension forces—on the surface of the water-cooled copper hearth. The molten metal does not wet the cold copper surface, and no signs of contamination by copper (or tungsten) can subsequently be detected in the alloy, even spectroscopically. It is usual to allow the button of alloy to solidify and then, by manipulating the electrode, to turn it over and remelt it to ensure thorough mixing. (R. 8.)

Argon Arc Welding. (*Argon Tungsten Arc.*) Welding in an inert atmosphere of argon using an arc struck between a non-consumable electrode (usually tungsten) and the work, the filler rod being added separately. The inert atmosphere is provided by directing argon into the weld area through a sheath surrounding the electrode, thus preventing oxidation of both the electrode and the weld pool. In the United Kingdom, practice has confined itself to argon because of the non-availability of helium (*Heliarc*). Both carbon and tungsten have been tried as electrode materials but the latter proved to be more satisfactory. The argon arc process is particularly suitable for welding stainless and heat-resisting steels, copper, aluminium, and magnesium. (Cf. ARGONAUT WELDING.) (M. 79.)

Argon Metal Arc Welding. An electric welding process in which the arc is maintained in a shield of argon gas either between a tungsten electrode and the workpiece, or between a filler metal electrode and the workpiece. The filler metal electrode is supplied as a coil of wire which is deposited as filler metal across the arc into the weld. The process is applicable to either machine- or hand-welding.

Argonaut Welding. An automatic welding process using an inert gas shielded arc with a self-adjusting consumable electrode. It is suitable for welding heavy-gauge aluminium plate, stainless and heat-resisting steels, and copper-base alloys. (Cf. ARGON ARC WELDING.)

Argon Tungsten Arc Welding. (See ARGON ARC WELDING.)

Armco Iron. A nearly pure commercial iron, manufactured by the American Rolling Mill Co., and cast into ingots. It contains less than 0·1% impurities, e.g. *carbon* 0·012%, *manganese* 0·017%, *phosphorus* 0·005%, *sulphur* 0·025%.

Armstrong Density Bottle. For rapid measurement of the volume of small irregular solids. The wide-mouth stoppered bottle is connected to a burette and the bottle filled with water to the mark on the stem, the level in the burette being near the bottom of the scale. Most of the water is then sucked up into the burette while the bottle is opened and the solid inserted. The water is then run back to the original mark and the difference of the burette readings is the volume of the solid.

Armstrong Process. A method for the production of *composite steel billets* by *forging* or *rolling*. The bond between the two metals comprising the billet is formed by electrolytic iron deposited on the surfaces to be united. During heating, diffusion occurs between the electrolytic iron and the basis metal, and forging or rolling produces a perfect weld free from oxide. Where there is a great difference in hot-work ductility between the two metals comprising the billet, special rolls and guides must be used to guard against flow of the more ductile metal around the less ductile one. (G. 54.)

Arnold, John Oliver, F.R.S., D.Met. (1858–1930.) A professor of metallurgy at the University of Sheffield. He carried out pioneer researches on the physical influence of elements on iron and the microstructure of hardened steel, and in particular of the influence of vanadium.

Arnold's Fatigue Test. In this test a collar fits over the top of a test piece, which is ⅜ in. diam. and 5 to 6 in. long and rigidly clamped at the lower end. The collar is given a reciprocating motion causing it to bend the piece alternately backwards and forwards through a distance of ⅜ in. on either side of the vertical. The standard speed adopted is 850 alternations per minute, and the number of alternations to fracture is recorded.

Arrest Points. (See CRITICAL POINTS.)

Arrhenius Theory of Electrolytic Dissociation. This theory states that the molecule of an electrolyte can give rise to two or more electrically charged atoms or ions.

Arsenic. (*As.*) Atomic weight 74·91. Specific gravity 5·73. Melting point 814° C. A soft, brittle element, seldom found free in nature, but occurring in many minerals. It is *allotropic*, with metallic and non-metallic properties. Arsenic is added to antimonial lead alloys and white bearing metals for hardening purposes and to increase fluidity. As any arsenic present in ores charged into the blast furnace is reduced and enters into the pig iron it is sometimes present in steel, in which it tends to induce *red shortness* whilst it increases the tensile strength and hardness and decreases the ductility. Brittleness, as measured by the *impact test*, is appreciably increased by the presence of arsenic. In these respects its effect appears to be similar to that of phosphorus but much less marked. Arsenic appears to have no effect on corrosion properties. (C. 3.)

Artificial Ageing. (See AGEING.)

Artificial Sand. Finely crushed rock.

As. Chemical symbol for *arsenic.*

A.S.A. American Standards Association.

Asbestos. The commercial name of several fibrous silicate minerals, e.g. serpentine, tremolite, etc. Asbestos is extremely fire resistant and for that reason and also for its low thermal conductivity it is used as a heat insulating material and for such purposes as fireproof curtains and shields. Asbestos textiles offer retention of strength at high temperatures, electrical resistance and a considerable degree of resistance to water and chemicals.

Asbolite. (See BLACK OXIDE OF COBALT.)

A proprietary carbon dioxide. It consists of asbestos fibre impregnated with dehydrated caustic soda.

As Cast. A term applied to steel castings which have not been submitted to heat treatment after casting. (See Plate VIII(a).)

As Drawn. Material in the cold drawn condition without subsequent heat treatment.

As Forged. A term applied to forgings, as delivered from the forge, which have received no subsequent treatment of any kind.

As Rolled. A term applied to rolled products, as received from the rolling mill, which have received no subsequent treatment.

A.S.E.E. Association of Supervising Electrical Engineers.

Askania Microscope. An instrument, of German manufacture, for the measurement of the profiles of extremely small dies.

Aslib. Association of Special Libraries and Information Bureaux. (See INFORMATION SERVICES.)

A.S.M. American Society for Metals.

A.S.M.E. American Society of Mechanical Engineers.

A.S.M.E. Free Bending Test. This is a modified method of free bending, devised for application to weld metal. The criterion of the test is the strain at the outer fibres when the first crack is set up. A set is first given to the ends of the specimen, and transverse pressure afterwards applied to the ends, inducing flexure in the middle section.

As_2O_5. Chemical formula for arsenic oxide.

Aspirator. A suction pump operated by means of a water tap.

A.S.R.E. American Society of Refrigerating Engineers

A.S.S.A. Alloy Steel Stockholders' Association.

Assay. The estimation of metals in ores by chemical analysis and heat treatment.

Assay Ton. It is usual to express the results of an assay in troy oz. of metal per ton of ore. In order to simplify evaluation, the assayer invariably determines the amount of metal present in either an assay ton of the ore (i.e. 32·66667 grams) or a fraction or multiple of that unit. In the former case milligrams of metal found in the assay are equal to troy ozs. of metal present in a ton (2240 lb.) of the ore.

Assel Elongator. A mill used in one stage of the production of seamless tubes. After the tube leaves the piercing mill, a bar is inserted into it. The tube,

which is still hot, and contains the bar, is then fed into the three revolving rolls of the elongator. These rolls are designed and installed in a manner which elongates the tube and produces the desired wall thickness.

Associations. (See Appendix V.)

Asterism. In X-ray diffraction patterns, the appearance of streaks or bands approximately along radii of the pattern. (A.27.)

A.S.T.M. American Society for Testing Materials.

A.S.T.M. Comparative Method of Designating Grain Size. A method in which the image of the structure of a suitably treated specimen is compared with a series of standard grain size charts. These charts are indexed from No. 1 to No. 8, each representing some mean number of grains per square inch at a magnification of 100.

Aston-Byers Process. (See BYERS PROCESS.)

Aston Iron. A product of the *Aston-Byers Process* claimed to have all the essential properties of wrought iron.

A.S.W.D.K.W. Amalgamated Society of Wire Drawers and Kindred Workers.

A.T. *Ampere Turns.*

At. No. *Atomic Number.*

A.T.A. American Transit Association.

Athyweld. (See ATOMIC HYDROGEN ARC WELDING.)

Atm. Abbreviation for atmosphere.

Atmidometer. An instrument for measuring the evaporation of water, ice, and snow.

Atmolyzer. An instrument for illustrating the separation of gases.

Atom. The smallest weight of an element which can take part in a chemical reaction. It has a very small, dense, positively charged nucleus, composed of *protons*, i.e. particles of a positive charge weighing $1{\cdot}00758 \times 10^{-24}$ grams, and *neutrons* which carry no electrical charge and weigh $1{\cdot}00893 \times 10^{-24}$ grams, the greater part of the weight of the atom being concentrated in the nucleus. Surrounding the nucleus are electrons moving about it in elliptical and circular orbits in comparatively empty space. The electrons are electrified particles of a negative charge weighing 10^{-27} grams. Different types of atoms differ in the size of nucleus and in the number of orbital electrons. The size and weight of an atom are important factors in metallurgy as they affect its behaviour in metal crystals The number of electrons surrounding the atom nucleus and their pattern is also important because this determines many of the physical and chemical characteristics of the element. (H. 38.)

Atomat Gauge. An instrument which measures the weight per unit area of the material passed through it. (I. 17.)

Atomic Arc Welding. (See ATOMIC HYDROGEN ARC WELDING.)

Atomic Energy Commission, Oakridge, Tennessee, U.S.A.

Atomic Energy Research Establishment, Harwell. (A.E.R.E.) The research establishment for the British atomic energy project.

Atomic Fission. The break-up of the nucleus of the atom, often accompanied by a large evolution of energy.

Atomic Heat. The quantity of heat required to raise the temperature of one gram-atom of an element 1° C.

Atomic Hydrogen Arc Welding. (*Athyweld.*) In this process an *A.C.* arc is maintained between tungsten electrodes, and each electrode is surrounded with an annular stream of hydrogen. In passing through the arc the molecular hydrogen is dissociated into its atomic state. The recombination of the hydrogen atoms results in very great liberation of heat which is used for fusing together the metals to be joined. This method has been found satisfactory in the welding of 18/8 types of steel and is particularly useful where, after bright polishing, a perfect match of colour is required between the weld metal and the parent sheet or casting. Distortion from the flame is comparable with that experienced with oxy-acetylene welding. (M. 20.)

Atomic Hydrogen Welded Tube. Tube produced from strip, usually of stainless or heat-resistant steel, by forming it into the desired diameter and welding the joint by the atomic hydrogen process.

Atomic Number. The number of positive charges on the atomic nucleus. This charge of the nucleus is the essential feature which distinguishes one element from another and determines the position of the element in the *periodic table.*

Atomic Planes. The layers along which the *atoms* are arranged within the crystal.

Atomic Theory. All elementary forms of matter are composed of very small unit quantities known as *atoms.* Atoms of a given element all have the same positive charge on the nucleus, the same size, and approximately the same weight. Atoms of different elements have different positive charges, different sizes and usually different weights. Atoms of the same or different elements unite with each other to form very small unit quantities of compound substances called molecules.

Atomic Volume. The volume occupied by one gram-atom of an element.

Atomic Weight. The relative weight of an atom of an element, taking the weight of an atom of oxygen as 16.

Atomization. The dispersion of a molten metal into particles. The simplest form of atomizing equipment comprises a crucible containing the molten metal which passes, by gravity, through an orifice. The stream of metal is disintegrated by high-pressure air, steam or water impinging on it. (M. 142.)

Atomizer Test. A test for the detection of the presence of oils and fats on metal surfaces. A panel of metal to be tested is hung up dry, then bathed in a spray of distilled water from the atomizer, which is about two feet away. After some 30 to 45 seconds the spray is shut off and the panel inspected. Where no oil or fat is present, the fine droplets of water coalesce and form a smooth film, while the presence of oil or fat causes the droplets to stand out like tiny beads from the greasy surface. It is claimed that this test is 160 times more sensitive than the common wetting test used to detect grease on metal after cleaning in an alkaline dip. (E. 72.)

Atrament C Phosphating Process. This is a modification of an earlier zinc process, and uses 4·8 kg. acid zinc phosphate solution per 100 litres water, to which is added 0·51 kg. zinc chlorate solution as accelerator. The operating temperature is 92° to 95° C. and the time required is only 2 to 10 minutes. In this process, the precipitation of insoluble zinc phosphate is minimized. The chlorate oxidizes the dissolved iron to insoluble ferric phosphate, the bath liquor remaining practically free from iron and retaining its $Zn(H_2PO_4)_2$ content. The resultant coating, which has a thickness of 1·5–5 μ, is almost wholly zinc phosphate and has good durability, flexibility, and insulating properties. The consumption of P_2O_5 is small. The process is suitable for all types of iron and can be used both for rust protection and for preparing the surfaces for drawing operations. Zinc and zinc alloys may be treated in the same bath with iron and steel. The *Cold Atrament process*, which can be operated at room temperature, uses 5·25 litres of acid zinc phosphate and 4 litres of accelerator per 100 litres of water. For easily-treated types of iron, only 3·5 litres of phosphate is needed. Coatings of 1–3 μ are obtained having a flexibility well suited to cold-drawing operations. The consumption of chemicals is even lower than with the C process, and zinc and zinc alloys can also be treated at the same time as iron and steel. (R. 45.)

Au. Chemical symbol for *gold*.

Å.U. *Ångström Unit.*

Audigage. A portable, self-contained instrument designed to measure the wall thickness of a wide variety of materials, including steel, from one side only. A vibrating quartz crystal is placed in contact with one side of the material under test so that an ultrasonic wave is transmitted into the material. This wave travels in a narrow beam through the material and is reflected by the opposite surface. The difference in frequency between any two adjacent signals is measured on a scale which is calibrated in frequency. A conversion scale on the instrument panel shows the thickness corresponding to the measured frequency difference.

Austempering. An interrupted quenching process which consists essentially of heating steel to an appropriate temperature above the critical range to render it austenitic and then, instead of cooling it to room temperature in one of the conventional cooling media, transferring the steel to a hot quenching bath maintained at a predetermined, constant temperature below the critical range, but above the martensitic change point (*M_s point*) usually between 260° and 370° C; the steel is held at this temperature for a certain time to ensure the complete direct transformation of the austenite in the final products (e.g. *pearlite* and *bainite*), after which the material may be cooled to atmospheric temperature in any convenient manner. (See also CRITICAL COOLING RATE.)

Austenite. The allotropic form of iron (gamma iron) which has a face centred cubic lattice, the parameter of which increases with increasing carbon content. Austenite, containing only carbide of iron in solution, is not stable at ordinary temperatures, nor can it be completely retained in solution by quenching, but its stability is greatly increased by the addition of certain alloying elements. (PLATE IX(d).) (See also ALLOTROPY, AUSTENITIC STEELS, GAMMA IRON, and IRON-IRON CARBIDE DIAGRAM.)

Austenitic Grain Size. The size developed by the grains of austenite when a steel is heated under certain conditions. It is largely controlled by the deoxidation conditions in steelmaking. The grain size may be determined by actual measurement using an eye-piece *micrometer* scale or similar device. Standard charts have been prepared by the American Society for Testing Materials (A.S.T.M. Standards, 1955, Pt. I, Plate I). (See also INTERCEPT METHOD.)

Austenitic Steel Core Process A process used in making hollow steel

drills. A hole is made in the centre of the drill steel billet and a rod of austenitic steel inserted therein. The billet is then heated, rolled and cooled, after which the rod is removed, leaving a hole through the entire length of the bar. Compared with the drill steel itself, the austenitic steel has a greater coefficient of expansion on heating and greater contraction on cooling. An additional feature is its extraordinary capacity to stretch evenly along its entire length before fracture takes place, a factor greatly facilitating its removal from the drill rod when pulled from both ends. An austenitic core steel offers considerable resistance at rolling temperature, which not only assists in leaving a smooth hole surface but contributes greatly in ensuring a good grain structure in the drill rod. (C. 28.)

Austenitic Steels. Steels consisting of *austenite*, which, owing to the presence of high percentages of certain alloying elements such as *manganese* and *nickel*, are stable at normal temperatures. Typical examples of austenitic steels include 14% manganese, and the corrosion-resistant type containing about 18% chromium and 8% nickel.

Austenitic Welding. (*Krupp Welding Process*.) The use of welding rods of austenitic corrosion-resisting steel (preferably 25% chromium, 20% nickel) in welding not only austenitic steels of similar composition, but including mild steel, carbon steel and cast iron. (K. 53.)

Austenitizing. The process of forming austenite by heating a ferrous alloy into the *transformation range* (partial austenitizing), or above the transformation range (complete austenitizing).

Autocatalytic Reaction. One taking place more readily at high rates than at low rates.

Autoclave. A vessel, usually constructed of thick-walled steel, for carrying out chemical reactions under pressure and at high temperatures.

Autoclino. An automatic, shell-moulding machine, designed for continuous production of half-shells at regular intervals. It consists essentially of an invertible support for the pattern plate, a sand-mixture hopper, and an infra-red heater. (I. 75a.)

Auto-Crucible Method. (See DRIP MELTING.)

Auto-Frettage. A cold working process, chiefly applied to cylinders and tubes of heavy wall thickness, e.g. guns. Auto-frettage may be effected by expanding the bore by hydraulic pressure, which, in turn, sets up a positive permanent deformation in some or all of the surrounding layers. This hydraulic pressure expands the cylinder until practically all the metal has been stressed beyond its elastic limit. On removing the applied pressure the cylinders are left in a state of internal stress with compressive stress at the bore and tensile stress at the outside. Thus, before failure can occur, any bursting force acting from the bore must overcome the superimposed compressive stress prior to overcoming the yield and maximum stress.

Auto-Punch. A hardness-testing instrument which operates by pressing the ball indenter on the surface to be tested. At a certain stage of the compression a trip causes a spring load hammer to strike the ball holder, with the result that the ball is pressed into the surface of the test material with a constant amount of energy. The diameter of the resulting impression is measured by a microscope and from a calibration curve or chart supplied with the instrument the equivalent Brinell number is obtained. (W. 68.)

Autogenous. Literally "of the same composition", and when applied to welding indicating that the weld is of substantially the same composition as the parent metal.

Autogenous Pressure Welding. A process in which the two pieces to be welded are pressed together at room temperature and then heated to a temperature below the melting point of the alloy by means of two burners. Recrystallization occurs which will give a joint showing physical properties similar to those of high-quality gas welds. Pressure-welding machines for welding tubes and round bars with cross-sectional areas up to 45,000 sq. mm. are available. (R. 12.)

Autogenous Welding. A method of uniting two pieces of metal by melting their edges together, any added weld metal being of the same composition.

Automatic Atomic Hydrogen Welding. This process is essentially the same as manual *atomic hydrogen welding*, except for special provisions for automatically controlling the factors involved in the process.

Automatic Bare Metal-Arc Welding. A welding process which employs a bare electrode, automatically fed to the work, and some flux which will stabilize the arc. There is no shielding medium, although the flux may have the effect of shielding incident to its prime purpose of stabilizing the arc. This process is used where low-cost welding and speed are of prime importance. A bare wire with a very light flux coating is fed through a nozzle which directs the arc

to the work. The arc length is controlled by electrical and mechanical devices and is dependent upon the arc voltage. In some modifications of this process, the wire is knurled in order that more flux can be incorporated into the wire for stabilizing the arc. (A. 38.)

Automatic Carbon-Arc Welding. A machine metal-arc welding process which uses carbon or graphite electrodes for making and maintaining the arc, and a welding rod to provide filler metal, where required. The equipment for this process consists of a carbon electrode which is usually rotated and surrounded by a magnetic field. The magnetic field stabilizes the arc to give uniform arc action. The welding rod used to supply filler metal is fed into the arc stream through a tube. Provisions are made for controlling the speed of the wire feed and for the maintenance of the desired arc length. The arc length is related to the arc voltage and automatic electrical and mechanical devices are used to maintain the desired arc length or arc voltage. (A. 38.)

Automatic Oxy-Acetylene Welding. The same as manual *oxy-acetylene welding* except that multiple flames are used and provision is generally made for moving either the torch or work so that welding may progress along the joint. (A. 38.)

Automatic Plug Rolling Mill. A mill used in the production of seamless steel tubes. It consists of a pair of grooved rolls, one of which is arranged to move mechanically for a rapid opening of the pass. A removable mandrel is supported in the groove on the end of a fixed bar, which is longer than the rolled pipe Stripper rolls encircling the mandrel bar are located behind the main rolls. These are likewise moved mechanically for opening their pass. A round bar is first pierced in a rotating piercing mill at forging temperature and is then passed through this roll stand twice, being rotated through 90° between the passes so that the entire surface receives an equal and similar treatment. (W. 74.)

Automatic Plug Mill Process. A process for making seamless steel tubes, in which a round bar is first pierced in a rotary piercing mill at forging temperature, and then passed through driven grooved rolls over a plug in the *Automatic Plug Rolling Mill.*

Automatic Shielded Metal-Arc Welding. Essentially the same as manual *shielded metal-arc welding* except that means are provided for automatically feeding the covered electrode and for moving the arc along the joint to be welded. (A. 38.)

Automatic Welding. Automatic metallic-arc welding may be classified under the following three broad headings: the *flux-controlled process*, in which the electrode is gravity fed to the component, and the thickness of the flux coating determines the arc gap; the *visible-arc process*, which has automatic motor-controlled electrode-feed mechanism and uses either a continuous electrode of bare wire, lightly fluxed, or heavy flux-coated electrodes; and the *submerged arc process*, which has similar electrode-feed mechanism and control, but in which the molten pool and arc are not visible, being submerged in the powdered flux. (L. 8)

Automation. A word coined by the Ford Motor Company to designate automatic feeding, unloading and handling of work to, from and between production machines.

Autoradiography. This consists in placing a photographic film in contact with a surface which is known to contain radioactivity. The degree of blackening of the film after development is an indication of the amount of radioactivity present. (F. 10)

Auxiliary Lift. In *resistance welding*, a device or means to permit manual or power operation of the top electrode holder or arm beyond and independent of its normal welding stroke.

Auxiliary Operations. In forging, the term relates to the additional processing of the piece to obtain contours or surface conditions which cannot be attained by normal forging operations. Such operations include *coining* and *straightening*.

Avery Brinell Tester. A hardness-testing instrument based on the weighing machine principle, the specimen resting on the weighing platform, connected by levers to the steelyards and weights Load is applied by the hand wheel and gearing, to the spindle carry- the ball, till the steelyards rise. The counterpoises are to balance the weight of heavy specimens and the handwheel is for quick movement of the spindle. Loads are variable from 30 to 3000 kg., and the calibration is by dead weight loading. (H. 9.)

Avery Brownsden Wear Machine. A machine for the testing of metals and lubricants. The indenter rotates in the form of a hardened steel wheel 1 in. diam. of radiused periphery, the dimensions of the oval impression giving a direct measure of wear. Time, 15 min.; load 5 to 30 lb.; speed 500 r.p.m.; thickness of specimen $\frac{1}{8}$ in. to $\frac{5}{8}$ in., any suitable size, e.g. 1 in. × 2 in.

Avery Cupping Test. The dimensions

of tool and dies in this test are identical with those in the *Erichsen machine*, but the Avery machine has the advantage of being portable; it can be used in an ordinary vice. The chief difference between the Erichsen and Avery tests is that the latter is provided with reversible dies, one side being plain and the other serrated The test piece is a strip 2 in. wide, and is tested first between the smooth dies with 0·05 mm. play as in the Erichsen test, it is then moved along and tested while clamped tightly between the serrated jaws It is suggested by the makers that the difference between the values given by these two tests is an indication of the workability of the metal, as distinct from the ductility, giving a value which is important in relation to *pressing* operations. (G. 37)

Avery Direct Reading Hardness Tester. A machine employing the *Rockwell* principle in that a standard minor load (10 kg.) is first applied. The indenter being already slightly embedded in the specimen, the pointer of the dial gauge is turned back to zero and a second or major load of 90 or 140 kg. is imposed on the minor load. When equilibrium is reached, the major load is released and the final position is read off from the dial whilst the minor load is still on The result is reported as a Rockwell number with the appropriate Rockwell indicating letter

Avery Fatigue Testing Machine. A machine designed for reversed-plane bending of flat, round or tubular specimens. By the use of special grips, it can also be used for the production of alternating torsional or combined bending and torsional stresses. If required, the specimen can also be subjected to an initial static load with alternating stresses superimposed, a condition emulating service conditions as closely as possible.

Avery Horizontal Structure-Testing Machine. A testing machine built for research into the strength of structural components of aircraft The machine weighs some 250 tons and measures 75 ft. 6 in long, 16 ft 6 in wide, and 15 ft 1 in. high above ground level It consists of a main frame in which a moving tension and compression crosshead is coupled by four tension bars to a moving ram crosshead To this ram crosshead are coupled four packingless rams and cylinders, each of which is capable of a maximum effort of 250 tons. (E. 27.)

Avery Self-Indicating Universal Testing Machine. A machine made in capacities of from 10 tons to 100 tons The load is indicated on a graduated dial, and both weighing and straining are effected through the medium of hydraulic pressure, which is applied simultaneously to the main cylinders of the straining gear and to a small cylinder housed in the load indicator cabinet. (E. 18.)

Avery Torsion Testing Machines. (See TORSION TESTING MACHINES.)

Avogadro's Hypothesis. Equal volumes of different gases at the same pressure and temperature contain the same number of molecules.

Avogadro's Number. The number of *molecules* contained in the gram molecule weight of any gas.

Avoirdupois. The system of weights used in the United Kingdom. (See Appendix II.)

A.W. *Atomic weight.*

A.W.A. American Wire Association.

A.W.W.A. American Water Works Association.

Axial Ratio. In crystals. In the tetragonal system and in the hexagonal division of the hexagonal system, the ratio of the parameter for the principal crystallographic axis of the highest multiplicity to the parameter for either one of the other principal axes, usually C = c/a; in less symmetrical systems the continued ratio of all three parameters, usually written a:b.c. (A. 27.)

Axial Stress The *stress* set up in a body in the direction of the axis.

Axis. In crystallography. One of three noncoplanar intersecting lines, fixed with respect to a crystal, which meet any crystal plane at points whose distances from the intersection of the axes, in terms of three parameters (a, b and c), one for each axis, are in the ratios of small integers. The principal crystal axes are those about which the symmetry is the highest possible to the crystal considered. Less properly, the length of an edge of the unit cell. (See PARAMETER.) (A. 27.)

Axis of Symmetry. In a crystal, a line about which a rotation through 360 degrees/N (where N is 2, 3, 4 or 6), with or without a translation parallel to the line, and with or without a reflection in a plane perpendicular to the line, replaces every element (point, line and plane) of the crystal by an equivalent element. The axis is said to be N-fold and is a rotation axis if neither translation nor reflection is involved, it is a *screw axis* if any other than a primitive translation is involved, and is a rotary-reflection axis (N not equal to 3) if reflection is involved (A. 27)

Azimuth. The angle which the vertical plane of a line makes with the meridian plane.

Azote. The name first given to nitrogen by Lavoisier.

Azotometer. An instrument for measuring or determining the proportion of nitrogen in air or in a mixture of gases.

B

B. (*a*) Chemical symbol for *boron*. (*b*) Flux density. (See MAGNETIC FLUX.) A term used to designate magnetic quality. (*c*) (See INDUCTION, MAGNETIC; INDUCTION, NORMAL.)

B_b. (See INDUCTION, BIASED.)

B_d. Remanent induction, values of induction on the demagnetization curve. (See REMANENCE.)

B_D. ($B\Delta$). (See INDUCTION, INCREMENTAL.)

B_i. (See INDUCTION, INTRINSIC.)

B_m. Maximum induction in a hysteresis loop.

B_r. (See Induction, Residual.)

B_{rs}. (See RETENTIVITY.)

B . (See INDUCTION, SATURATION.)

Ba. Chemical symbol for *barium*.

Babbitt's Metal. An antifriction bearing metal which usually contains about 85% to 90% tin with 7% to 11% antimony and 3·5% to 8·0% copper. The original composition recommended by Babbitt contained 24 lb. tin, 8 lb antimony, and 4 lb. copper and to every 1 lb. of this alloy, when melted, an additional 2 lb. of tin was added to form the final alloy

Babcock Multi-Layer Welding Process. In this process a number of layers of metal are deposited one upon the other from coated electrodes, the layers being staggered in the groove to provide a certain amount of overlapping Each layer has the effect of refining the grain structure of the one beneath and when the groove has been filled, additional layers are deposited in the same way above the plate level and subsequently chipped off, thus enabling the metal at the weld surface to be given a degree of grain refinement. The welding machines employed have automatic arc control and electrode feed, but electrode centralization is effected by the operator. The A.C. welding supply can be varied between 350A and 700A, according to the electrode used, with an arc drop of about 35 V. (E. 28.)

Babcock and Wilcox Continuous Casting Process. A method consisting of continuously casting a high melting point metal in a vertically elongated, liquid cooled, open ended moulding tube. (B.1.)

Baby Brinell. A hardness test on the Brinell principle using a smaller ball and a correspondingly lower load. The diameter of the impression is measured to the nearest thousandths of a millimetre and the Baby Brinell hardness number obtained by reference to a chart.

Bacco Process. A casting process in which molten metal is poured into a heated die. Constant pressure is exerted during solidification, followed by increasing pressure to obtain a forging action. Increased strength, improved finish, and less machining are some of the advantages claimed for the production of ferrous and non-ferrous parts by this process. (D. 50.)

Bachite Process. A surface colouring process which, it is claimed, can be applied to any of the straight chromium or chromium nickel steels. A colourless chemical solution is sprayed on to the surface and heat is applied. The Bachite colours are claimed to be adherent and apparently integral with the surface For delicate colours a high polish is essential. (B 111.)

Bacillae Test. (See PENETRAMETERS.)

Back Draft. A reversed taper which prevents the withdrawal of the *pattern* from the *mould*

Back End. (See TAIL MARKS.)

Back-Pull Wire Drawing. In wire drawing, the metal is made to flow by tensile stresses due to the drawing force, and compressive stresses, caused by the nip of the die. When back pull is applied, the metal flows under lower compressive stresses, thus reducing the force required to overcome friction in the die, thus, back-pull drawing is claimed to increase efficiency, since less energy is dissipated by friction. (See also MARSHALL RICHARDS' BACK-PULL WIRE DRAWING MACHINE.) (W. 65.)

Back Reflection. X-ray diffraction at deviations near 180 degrees, especially useful in precise measurement of interplanar distances. (A 27.)

Back Up Rolls. (*Backing Rolls*) The more massive rolls which support the relatively slender *working rolls* in, for example, a *four high rolling mill*.

Back Wall Pyrometer. An immersion *thermocouple*, consisting of a semi-permanent fixture attached to the back-wall of a melting furnace and manipulated through the back wall, by means of a light jib. The thermocouple arm consists of a heat-resisting steel tube, protected from steel, slag, and flame by means of plumbago sleeves. (M 75.)

Background. In *spectrographic analysis*, the background is produced by the light source from continuous radiation, incandescent particles, unresolved band spectra and from scattered light in the

spectrograph. On the photographic plate the spectral lines are thus superimposed on a dark continuum due to this continuous light. Background on a spectrogram should be distinguished from photographic or chemical fog which is the overall density of a photographic plate produced on development but is independent of the spectrographic exposure. The background is superimposed on the fog.

Backhand Welding. (*Backward* or *Right-hand.*) A method of welding in which the blowpipe is directed towards the completed weld.

Backing Board. (*Backing Plate.*) A second *bottom board* on which *moulds* are opened.

Backing Plate. (See BACKING BOARD.)

Backing Rolls. (See BACK UP ROLLS.)

Backing Run. (See SEALING RUN.)

Backing Sand. (*Filler Sand.*) Reconditioned sand used for supporting the *facing sand*, and forming the main part of the *mould*.

Backing Strip. A piece of steel, copper or other material placed behind a joint to facilitate a welding operation.

Backstep Sequence. A longitudinal sequence wherein the weld bead increments are deposited in the direction opposite to the progress of welding the joint. (See BLOCK SEQUENCE, LONGITUDINAL SEQUENCE, etc.) (A. 37.)

Backward Welding. (See BACKHAND WELDING.)

Baffle Plate. A wall in a fire box or furnace to deflect or change the direction of the flame. (A. 26.)

Bagnall-Bethel Patent Nozzle. A device for attachment to the nozzle of a ladle with the object of increasing the rate of teeming of the steel. It consists of a single- or multi-nozzle box fixed with a quick-acting bayonet joint below the ordinary nozzle. The orifice in the former is smaller than that in the latter, and when a suitable number of ingots have been poured through the smaller orifice the secondary nozzle box is removed with a rapid movement of a special spanner. (I. 54.)

Bagsar Cleavage Tear Test. A test to determine the susceptibility of steel plate to the development of cleavage or brittle fractures. The test coupon used is essentially a short beam of rectangular cross section, which has a U notch at its top edge, and is subjected to tensile loading, eccentrically applied. The upper parts of the arms accommodate loading holes and provide the desired eccentricity of loading. (B. 4.)

Bail. Hoop or connection between the crane hook and ladle.

Baily Furnace. An electric resistance furnace having coke granules between carbon electrodes.

Bainite. An acicular aggregate of ferrite and carbide particles formed when *austenite* is isothermally transformed at temperatures in the intermediate range, i.e. above the *martensite* range and below the *pearlite* range. The properties obtained by this treatment have been claimed to be superior to those attained by full *quenching* followed by *tempering*. The structure of the bainite varies with the composition of the austenite from which it is formed and with the temperature of its formation. (See Plate IX(c).) (See AUSTEMPERING.) (K. 36.)

Bairstow's Repeated Stress Testing Machine. The machine consists of a single beam pivoted about a fulcrum with a rod to which appropriate weights are attached, suspended from each extremity. The specimen is fixed into two shackles, the upper attached to the beam, and the lower connected to a hydraulic straining cylinder. The weights attached to the rods are alternatively applied and released, thus subjecting the beam to small oscillations in the vertical plane. An additional weight, superimposed at different positions on the beam, exerts tension, compression, or static stress. (G. 36.)

Baked Permeability. The property of a moulded mass of sand, after baking at a temperature above 110° C. followed by cooling to room temperature, which allows gases evolved during the pouring of the metal into the mould to pass through it.

Baked Strength. The tenacity (compressive, shear, tensile, or transverse) of a sand mixture, when baked at a temperature above 110° C. followed by cooling to room temperature. (A. 26.)

Bakelite. A synthetic resin, named after L. H. Baekeland. It is the product of the condensation of creosol or phenol with formaldehyde.

Bakie. (See TUNDISH.)

Baking. (*Stoving.*) Treating wire or wire rods at comparatively low temperatures subsequent to *pickling*, in order to remove gases.

Balanced Steel. (*Semi-Killed.*) A *non-piping steel* in which no observable gas evolution takes place, but where sufficient gas is formed during solidification to balance or offset the normal shrinkage of the solidifying metal; numerous blowholes are produced and so the central shrinkage cavity or pipe is prevented or considerably reduced in extent. Balanced steels are only partially deoxidized and small additions of aluminium are made in the moulds, if necessary, to reduce the oxygen

content to that amount which will give an ingot with a flat or slightly bulging top.

Baldwin Atomat Radiation Thickness or Weight Gauge. This industrial type gauge operates on the following principle: a source of radioactivity in a suitable container, whereby radiation is restricted to the required direction, is so disposed that the radiation passes through the material to be gauged and thence on to a detector. The latter comprises a sealed chamber containing air which becomes ionized by the radiation, and is consequently able to transmit a minute current that is directly proportional to the extent of the radiation received. This current is amplified electronically. The radioactive source and the ionization chamber are mounted on opposite sides of the substance to be gauged with a working distance between them of about 1 in. The position of the material in the gap does not effect the accuracy of reading. The usual scanning area is $1\frac{1}{2}$ in. by 9 in. disposed along or across the direction of movement of material, as desired. (M. 44.)

Baldwin Creep Tester. A creep-testing machine, for elevated temperature work. It takes specimens 0·505 in. in diam. by $6\frac{1}{4}$ in. long. Time and strain indications are given by two counters, one of which counts the number of breaks in electrical contacts which are separated by the extensometer at each length increment of 0·00025 in. (P. 44.)

Baldwin-Omes Process. A method of forging shell direct from the square steel billet. The split die employed is circular when closed and with the closing of the die, the billet is squeezed at its bevelled corners and held symmetrically. A steel bushing in the die, guides the mandrel, and since only linear motion takes place, the piercing mandrel enters the square section billet in the centre, thus producing a perfect, concentric shell. (C. 59.)

Ball. (*a*) A rounded mass of spongy iron, weighing about $1\frac{1}{4}$ cwt. prepared in a *puddling* furnace. (*b*) A mass of tempered fireclay, used for forming the crucible in *crucible-steel* production. (*c*) A mass of compo or fireclay used in repairing refractory linings of furnaces or ladles. (*d*) A spherical indenter used in hardness testing.

Ball Burnishing. A method of developing high lustre on small stainless steel parts, by rotating them in a wooden lined barrel, containing water and burnishing soap, with stainless steel shot.

Ball Clay. An extremely plastic clay found in Dorset and Devon. The clay is so called because it used to be quarried by cutting into cubes or balls of about 30 lb. in weight.

Ball Furnace. A furnace for heating *piles* of puddled iron to a welding heat for forging into a bloom or slab.

Ball Furnace Pile. (See PILING.)

Ball Mill. A mill in which material is finely ground by rotation in a steel drum with pebbles or steel balls. The grinding action is provided by the collision of the balls with one another and with the shell of the mill.

Ball Race Steels. Steels for this purpose usually contain about 1% carbon and 1% chromium.

Ball Rammer. (See RAMMER.)

Ball Test. A test of directional strength made by pressing a 1-in. hardened steel ball into a smoothly reamed and chamfered 0·75-in. hole in a section of strip supported during the test by a hardened ring of 3 in. inside diam. on which the hole in the sample is centred, e.g. a straight-rolled strip fractures straight along the rolling lines, whilst the cross-rolled strip produces either random or curved breaks, unrelated to the rolling (H. 73.)

Ballentine Hardness Tester. In this instrument, a diamond point indenter, is held in constant contact with the test specimen by its own weight plus the action of a spring. Any movement of the indenter is followed by a lever and is registered by the action of the lever on the gauge. A magnet, adjustable by means of a thumb screw to give any height of hammer drop between 0 and 70 mm., allows a hammer to be released for a free fall to strike the indenter. The height of fall of the 320 g. hammer is fixed to give the desired energy of impact by means of gauge blocks inserted in such a manner that the gauge block is in contact with the top of the indenter and the base of the hammer. (P. 11.)

Balling. Aggregating iron particles into a rounded mass of spongy iron in the *puddling furnace*.

Balling Up. (*a*) A process that occurs in the *cementite* constituent of steels on prolonged annealing at 650° to 700° C., also called spheroidization. (*b*) The operation of forming balls in a *puddling furnace*.

Ballistic Galvanometer. A *galvanometer* in which the time of swing is long compared with the duration of the transient which the instrument is intended to measure.

Ballistic Test. A firing test carried out with projectiles against armour plate.

Bamboo Steel. A high carbon steel,

made in long flat bars which have ribs or corrugations at regular intervals along their length, so that it resembles bamboo. It was first made by water power and hand forging, which accounted for the ribs or corrugations. Steel of this type was exported to China and the Balkan States. In China it found ready favour, being used as edges to the knives fashioned from wrought iron. It was inserted into the edge of the piece of wrought iron intended for the knife blade. The whole assembly was then welded and hammered until the edge of the blade became extremely thin. It could then be given a keen cutting edge. (B 112.)

Banca Tin. Tin produced in the island of Banca, in the Dutch East Indies. (See TIN.)

Band Edge. (See MILL EDGE.)

Banded Structure. Light and dark parallel bands revealed by etching and formed by the elongation of segregated areas during rolling (L. 10.)

Bands. Flat, hot-rolled, finished steel products having thicknesses within the range 0·1072 in and 0 25 in. and widths from about $2\frac{1}{2}$ to 24 in.

Banking. A term applied in *blast furnace* practice when the production of iron is stopped, but the furnace remains full of stock. In preparation for banking, a coke blank is charged, consisting of from 60 to 200 tons of coke, and the blast is kept on the furnace until this blank is on the *hearth*, and in front of the *tuyeres* The remaining stock in the furnace has reduced *burden*. When the coke blank is in front of the tuyeres, the furnace is shut down, all slag drained out, and the furnace is then tightly sealed against air infiltration so that the coke will not be burned away, but will be available for the start up of the furnace. (See also DEAD BANKING.) (B 116.)

Banox. An amorphous metaphosphate compound, used as a preliminary treatment before wire-drawing It is found to have excellent rust-resisting properties, and to act as a lubricant; when wire is coated, by dipping with Banox before liming, it is found that the amount of lime applied is no longer critical It can also be used with wire flash-coated with copper, where it assists rust proofing. (S 123.)

Bar. (*a*) An elongated steel product, of uniform cross section, usually rectangular, circular or hexagonal Bar is generally produced by hot rolling from billets or cogged blooms, but it may be produced by forging. (See also BRIGHT STEEL BARS.) (*b*) A unit of pressure, equal to a million dynes per sq cm.

Bar Bend Test. The machine employed for this test consists essentially of a single flat top-plate of $\frac{3}{4}$-in. steel, drilled in the centre to admit a $4\frac{1}{2}$-in. diam. solid steel shaft, geared to provide a traverse of approximately 5 degrees of arc per second. Mounted upon the top-face of the shaft is a replaceable die, drilled to receive a 1-in. end of the specimen with sufficient freedom to prevent seizing and machined with a projecting radius. The dies are drilled from $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ in. stock and have respective radii of the size of the rod; but the ratio of specimen radius to bend radius can be varied. Over the projecting end of the specimen is a steel sleeve which projects to the plunger on an electric clutch. The side of the die is grooved to receive this sleeve to a depth permitting the specimen to bend 180 degrees flush with the die side. Also on the face-plate is a brass semicircle inscribed from 0° to 180°, and a pointer attached to the revolving shaft indicates the degree of bend. In operation, the specimen is inserted in the die, the sleeve is placed on the projecting end, the indicator is brought to zero, the sleeve depresses the plunger of the electric clutch against a 10-lb. spring, bending is begun at the constant rate of approximately 5 degrees of arc per second and, when the specimen fails, the reduction of load on the clutch spring cuts the electric circuit and stops the rotation automatically registering the degree of bend at which failure (not necessarily fracture) occurs (Z. 6.)

Bar Drawing. (*Mandrel Drawing.*) A term used in the production of cold finished seamless tubes where a bar is inserted into the tube and gripped so that both the tube and the bar are pulled through the die together. The release of the bar is accomplished by rolling which has the effect of expanding the bore of the tube sufficiently to release the mandrel.

Bar Hold. (See TONG HOLD)

Bar Mill. A *rolling mill*, with grooved rolls, for producing round, square, or other sections of bars. (See ROLLING MILLS)

Bar Weight. The weight of a sheet bar per foot.

Barber Pyrometer. A high precision disappearing filament optical pyrometer. It is portable, weighing only $2\frac{1}{2}$ lb., and is self-contained. The design of the optical system, the use of a strip filament lamp and measurement of filament temperature by a null balance resistance bridge instead of filament current are distinguishing features of the instrument. There are two ranges

(i) 800° to 1250° C., claimed to have an absolute accuracy better than ± 5° C., and (ii) 1100° to 1900° C., with an absolute accuracy of better than ±10° C.

Barcol Impressor. A hardness testing instrument comprising a casing adapted to fit the hand and a rear leg which bears on the work to be tested. A dial indicator connected to the indenter indicates the hardness of the metal to which the instrument is applied. To test the workpiece, it is merely necessary to put the impressor onto it and to press down so that the point is pushed into the work until it is stopped by the surrounding spindle; the reading on the dial is an indication of the hardness of the material. The point is a truncated steel cone hardened to a minimum of 66 Rockwell C. Its length is 1·340 in.; the tip has been ground to 0·00625 in. diam. and to an included angle of 24 degrees. (I. 4.)

Barcote No. 600. A leaded petroleum compound for protecting metal surfaces against corrosion. It may be applied by brush or spray. It is claimed that the film is rubber-like in nature so that it can expand and contract without cracking.

Bare Electrode. (See ELECTRODE.)

Bare Metal Arc Welding. A process in which fusion is obtained by heating with an electric arc between a bare or lightly coated electrode and the work. Neither *shielding* nor pressure is employed. Filler metal is obtained from the electrode. (A 37.)

Barffing Process. The process depends on the ability of iron to react with steam at a red heat to form black, magnetic oxide of iron, Fe_3O_4. The parts to be treated are placed in a sealed furnace and the oxidizing cycle proper commences when they have attained a temperature of 800° to 850° C. During this period, superheated steam is admitted to the chamber for a time, which is strictly dependent on the nature of the article being processed When the charge has been withdrawn from the furnace and cooled, the iron surface will have taken on a light-bluish slate colour. (M. 156.)

Barium. (*Ba.*) *Atomic weight* 137·36. *Atomic number* 56. *Melting point* 704° C. A metallic element which oxidizes rapidly in air and decomposes water at normal temperatures. Alloys of *lead*, barium, and *calcium* are used as bearing alloys, the barium giving additional hardness. It is claimed that barium has been used with success as an addition in the production of *nodular cast iron*.

Bark. The decarburized skin or layer just beneath the scale that results from heating steel in an oxidizing atmosphere. (A. 27.)

Barkhausen Effect. The discontinuous variation in magnetization in ferromagnetic substances. Work done on small single crystals has demonstrated that the magnitude of the Barkhausen effect is strongly shape-dependent and that the demagnetizing factor of the specimen is an important variable; the effect of a high demagnetizing factor is to reduce the magnitude of the Barkhausen effect and to produce a corresponding increase in the contribution of the reversible magnetization processes. (T. 6.)

Barley-Shell Markings. An etched structure found in high silicon irons when hydrofluoric acid is used as the etching reagent. (H. 85.)

Barnett Effect. The magnetization of a body due to its rotation.

Barrel. (*a*) The body of the roll which comes into contact with the product being rolled (*b*) That part of a forging which is of major cross section.

Barrel Finishing. (See TUMBLING).

Barrel Polishing. A method of finishing small stainless steel parts, carried out in two stages, consisting of *honing*, in which the work is loaded into the polishing barrel through a door in the side, together with an abrasive, water and soap, and the barrel is rotated, thus removing surface imperfections. This step is followed by *ball burnishing*.

Barrelling. A method of coating metals in which the articles are gently rotated in an inclined barrel with a very small quantity of lacquer until they are evenly coated, the lacquer drying at the same time. (T. 38.)

Barrett Effect. (See Magnetostriction.)

Barrier Materials. Materials such as lead and concrete which are used for protection from X-rays or gamma-rays in radiographic installations.

Bart Process. A method for the production of *Lectro-clad piping*, by which the internal surface of piping can be coated with a uniform and adherent coating of nickel, 0·007 to 0·030 in. thick. The coated piping can be heated, bent, formed and subjected to other fabricating processes without risk of peeling. (B. 19.)

Baryta Process. A method of determining the carbon content of steel, in which the sample is oxidized in a stream of oxygen and the carbon dioxide thus formed is absorbed in a baryta solution. (K. 16.)

Basal Crack. (*a*) A crack in the bottom end of an ingot caused by the lack of free contraction during freezing. (*b*) A crack in the root of a weld.

Basal Plane. In tetragonal and hex-

agonal crystals, a plane perpendicular to the c-axis. (A. 27.)

Base. A substance which neutralizes acids producing a salt and water, which will combine with hydrogen ions and turn litmus blue.

Base Metal. (*a*) A metal which becomes oxidized when heated in air, e.g. *copper*, *lead*, *zinc* and *tin*, as distinct from a precious metal, such as *gold* and *platinum*. (*b*) In electrometallurgy, a metal at the lower end of the *electrochemical* series, as distinct from a *noble metal*. (*c*) The preponderant metal in an alloy. (*d*) The metal to be welded or cut.

Base Metal Thermocouple. (See THERMOCOUPLE.)

Base Permeability. The physical property which permits gas to pass through packed dry sand grains containing no clay or other bonding substance. (A.26.)

Base Size. (*Common Drawn Size.*) As applied to wire, the term denotes the diameter in which it is *patented* or *annealed* before drawing to its finished diameter As applied to galvanized or tinned wire, the diameter in which it is galvanized, or tinned.

Bash and Harsch Test. A high temperature tensile test for electrical resistance wire, in which the wire is hung in tension under a predetermined load and whilst a current flows intermittently 2 min. on and 2 min. off.

Basic Bessemer Process. (See BESSEMER PROCESS.)

Basic Lining. In a melting furnace, the inner lining and bottom composed of materials that have a basic reaction in the melting process—either crushed burned *dolomite*, *magnesite*, magnesite bricks or *basic slag*. (A. 27.)

Basic Open-Hearth. (See OPEN-HEARTH FURNACE.)

Basic Oxide. A metallic oxide which reacts with water to form a base, e.g calcium oxide.

Basic Pig Iron. A special high phosphorus (2.0% to 2.5%) low sulphur (0·08%), low silicon (0·80%), pig iron made for the *basic open-hearth process*.

Basic Process. A method of steelmaking carried out in a furnace, either *open-hearth*, *Bessemer converter* or *electric*, lined with a *basic refractory*, such as *magnesite* or *dolomite*, the refining of the steel being carried out under a *basic slag*. This process is characterized by the fact that a slag rich in lime is produced and the sulphur and phosphorus pass into the slag during the working of the charge. (L. 12.)

Basic Refractory. A heat-resistant material consisting essentially of basic oxides, e.g. *magnesia* or calcined *dolomite*.

Basic Slag. A *slag* produced during the conversion of high phosphorus pig iron into steel by the *basic process*. It has a commercial value as a fertilizer owing to its high calcium phosphate content.

Basic Steel. Steel produced by the *basic process*.

Basin. (*a*) The term as used in the foundry, refers to a depression in the top of the *cope* which receives the molten metal before it flows into the *sprue*. (*b*) (See CRUCIBLE ZONE.)

Basis Box. The term as used in the tinplate industry is the unit of quantity for mill production and price calculation, equivalent to 31,360 sq. in. of sheet, e.g. 112 sheets 20 in. by 14 in. weighing 108 lb.

Basket Charging. A method of charging an electric furnace in which the roof and electrode gear form a separate structural unit from the furnace. The roof and the electrodes are raised and moved aside, whilst the charge, packed in a basket, is lowered over the furnace by means of a crane. The basket is then opened from the bottom and the contents allowed to fall into the furnace.

Basset Process. The process for the direct production of iron and steel from ore carried out in an inclined rotary furnace, 40 to 50 metres long and about 2·5 metres in diam. The iron ore, preferably finely powdered, together with limestone and the required amount of coal for reduction, is charged into the upper end of the furnace. Through a tuyere at the lower end of the furnace are injected pulverized coal and preheated air The proportions of air and pulverized coal are so regulated that the combustion will only produce carbon monoxide, thus preventing any oxidation or carburization of the metal during melting. In the same way, by regulating the proportions of the air and pulverized coal, the molten metal may be carburized to convert it into steel or cast iron, or impurities, such as silicon, manganese, phosphorus, etc., may be oxidized.

Bassett Process. A method for the simultaneous manufacture of iron and cement. Clinker is ground and separated by air and magnetic separators into cement and powdered iron. The latter has a composition similar to *grey iron*. The cement, although it contains some unseparated iron, has normal setting time and good strength. (K. 45.)

Bastard File. A file of medium cut, i.e. mid-way between smooth and rough. (See CUT.)

Bastard (Wrought) Iron. A material made from both iron and steel.

Bat. A thin slab of fireclay or other refractory material.

Batch Furnace. A type of *reheating furnace* in which the contents remain in a fixed position until discharged, i.e. the contents are charged in batches as distinct from a continuous furnace.

Batch Sintering. *Pre-sintering* or *sintering* in such a manner that the products are furnace-treated in individual batches. (G. 30.)

Bath. (*a*) The molten metal in the hearth of a steelmaking furnace. (*b*) A solution in bulk for the treatment by immersion, for example, in photographic, descaling, electroplating, or galvanizing processes.

•**Bath Sample.** (See SPOON SAMPLE.)

Batho Furnace. A modification of the *open-hearth furnace* in which the regenerators are placed outside the furnace, usually above floor level, and are quite separate from it.

Batoreometer. An instrument for measuring minute variations of thickness. The contact of a micrometer screw with the object to be measured is indicated by the passage of an electric current.

Batter. The slope in blast furnace walls e.g. at the stockline the walls of the furnace are parallel but below this the walls slope outward (*outward batter*) to allow for the swelling of the materials as the reaction proceeds. When the ore is reduced and the metal and slag become liquid there is a contraction in bulk which is countered by the inward slope (*inward batter*) of the walls toward the *tuyeres*.

Baumann-Steinrück Impact Hardness Tester. The essential feature of the apparatus is a hammer which, after a tension spring has been released, strikes a ball into the material to be tested. A measuring microscope is furnished for accurately ascertaining the size of the impression so made.

Baumann Sulphur Printing. A method of examining a ground and polished steel surface for sulphur segregations. The procedure consists of pressing a photographic bromide paper soaked in dilute sulphuric acid on to the surface under examination. The sulphuric acid in the bromide paper reacts with the sulphide in the steel, liberating sulphuretted hydrogen, which in turn reacts with the silver bromide in the vicinity, producing dark-coloured sulphide of silver.

Baumé Hydrometer. An instrument for measuring the specific gravity of liquids. The *Baumé scale* is so graduated that 0° is the point to which it sinks in water and 10° in a 10% solution of sodium chloride, both liquids being at 12·5° C.

Baumé Scale. (See BAUMÉ HYDROMETER.)

Bausch and Lomb Dust Counter. For general description see KONIMETER.

Bauschinger Effect. The decrease in compressive yield strength and increase in tensile yield strength obtained when a metal is plastically strained in tension beyond its yield point. (P. 28.)

Bauxite. A mineral consisting mainly of hydrated *alumina*, $Al_2O_3.2H_2O$, mixed with silica and iron hydroxide. It is the most important source of *aluminium*.

Bauxite Brick. A firebrick composed essentially of hydrated alumina and ferric oxide. Such bricks are used for the lining of furnaces where a neutral material is required.

Bauxite Cement. (See CIMENT FONDU.)

Bayer Process. A process for the production of *aluminium* from *bauxite*, by digesting the crushed ore under pressure in a hot caustic soda solution.

B.C.C. *Body-centred cubic.*

B.C.I.R.A. British Cast Iron Research Association.

B.C.I.R.A. Sand Compression Testing Machine. An instrument for the determination of the compressive bond strength of moulding sand. A rammed sample is placed on the platform of the machine and the load is gradually applied, the load which produces the collapse of the specimen being read off on an indicator.

B.C.P.M.A. British Chemical Plant Manufacturers Association.

B.C.S.O. (N.A.). British Commonwealth Scientific Office (North America).

B.D.S. Process. (See INKROM PROCESS.)

Be. Chemical symbol for *beryllium*.

Bé. Abbreviation for *Baumé Scale*.

B.E.A. British Electricity Authority.

Bead. A single longitudinal deposit of *weld metal* produced by a *fusion-welding* process.

Beading. Raising a ridge on sheet metal. (A. 27.)

B.E.A.I.R.A. British Electrical & Allied Industries Research Association.

Beak Iron. (See ANVIL.)

Beam. (*X-ray.*) A nearly parallel pencil of X-rays from a common source. (A. 27.)

Beam and Sling. Tackle used in conjunction with a crane for turning over the *cope* or *drag* of a *mould* prior to assembly. (A. 26.)

Beam Trap. A device on an X-ray diffraction camera for absorbing the undiffracted primary X-ray beam after it has passed through the sample.

B.E.A.M.A. British Electrical and Allied Manufacturers' Association. (Now obsolete.)

Bear. (*Old Horse, Sow, Salamander.*) The

mass of metal which is found below the hearth level of the *blast furnace* after the furnace has been blown out, and formed by the escape of molten iron through the hearth. Bears of up to 1000 tons in weight have been found. (S. 105.)

Bearing Metals. *Anti-friction metals* varying widely in composition, e.g. *bronze* or *white metal*. They are used for that part of the bearing which is in contact with the *journal*, owing to their low coefficient of friction when in contact with a steel surface.

Bearing Seals. These seals are used to prevent the entry of water and scale into the roll-neck bearings of steel *rolling mills*. The two types of seal in common use are the shaft, in which the sealing element has a sharp edge in constant contact with the shaft so that the surface films of oil, grease, or water are cut, and the end-face or surface type, in which the sealing element is a lapped surface, in tight contact with a lapped surface on the rotating shaft. (K. 52.)

Bearingizing. A process for the accurate finishing of holes and surfaces. A tool employs a peening action, and consists of an arbor on which are fitted a rotating roll cage and several bushings that serve as pilots. This peening action increases the hole size a precisely predetermined amount, usually about 0·0005 to 0·001 in. and provides the surface finish required. (I. 38.)

Bearings Roll. That part of the *rolling mill* in which the roll neck rotates; it may be lined with brass, white metal, fabric or phosphor bronze

Beating. (*a*) Producing very thin sheet by hammering. (*b*) Forming sheet by hammering into or over a form of the desired shape, usually made of wood. (See HAMMERING.) (A 27.)

Beck Iron. (See ANVIL.)

Beckern. (See ANVIL.)

Becking. Increasing the diameter of a steel ring such as a tyre or drum by forging on a *becking bar*, the billet being squeezed between the upper tool and the bar. (See BECKING MILL.)

Becking Bar. A mandrel inserted through a forging and supported at each end by *becking stands*, the wall of the forging then being pressed between the mandrel and the hammer.

Becking Mill. The first of a series of three mills used in the rolling of *tyres*. It consists of a rotating table through which projects a central mandrel, whilst a heavy outside roll is mounted on a diagonal shaft. The hot work in the form of a punched and flattened bloom is mounted over the central mandrel and revolved in contact with the outside pressure roll, thus giving the punched work the rough form of a tyre. The external or tread profile is formed by the pressure roll and the central mandrel determines the form of the bore.

Becking Stands. Stands which support the *becking bar*.

Beckmann Thermometer. A large bulbed mercury thermometer used for precision measurements of small changes in temperature over a very narrow range. The instrument can be set to cover different ranges by removing or adding mercury to the indicating thread by means of the mercury reservoir with which it is provided.

Beck's Hydrometer. A hydrometer in which the scale is so graduated that 0° corresponds to a specific gravity of 1·00 and 30° to a specific gravity of 0·85.

Becquerel Effect. Production of an *e.m.f.* when two identical electrodes immersed in an electrolyte are illuminated unequally.

Bed Charge. The first coke charged into the *cupola* upon which the melting is carried out.

Bed Plate. (See CUPOLA.)

B.E.D.A. British Electrical Development Association.

Bedding In. Sinking a *pattern* into the sand in *moulding*.

Beehive Oven. A coke oven.

Beeny's Drill Penetration Test. In this test, machinability is measured by the depth of penetration of a tungsten-carbide-tipped drill, ½ in. diam., under a load of 51 lb. after 100 revolutions. (R. 51.)

Beer's Law. The degree of absorption of light depends on the thickness of the layer traversed and on the molecular concentration of coloured substance in that layer.

Beilby, Sir George. (1850–1924.) An English metallurgist chiefly remembered for his work on the structure of the polished surface layer on metals.

Beilby's Layer. A non-crystalline layer formed on the surface of metals during mechanical polishing.

Belaieff's Etch. A method of revealing the structure of high manganese steels by first etching with 3% nitric acid in ethyl alcohol and then with *Le Chateliers'* No. 1 reagent, the precipitated copper being dissolved off by strong ammonia.

Bell. (See WELDING BELL.)

Bell and Hopper. (*Cup and Cone.*) The charging apparatus at the top of a *blast furnace*, so devised that the raw materials can be fed into the furnace whilst the escape of gas is prevented. A more recent improvement is the *double bell and hopper*, which consists

of placing a second and smaller bell and hopper above the first and making a gastight space between the two.

Bell Furnaces. Sealed containers in which coils of strip are heated and cooled in a protective atmosphere usually of town gas.

Bell, Sir Isaac Lowthian, F.R.S. (1816–1904.) A noted ironmaster, who through his work and experiments did much to lay the foundations of our knowledge of the metallurgy of iron.

Bell's Reaction. The reaction entailing the decomposition of carbon monoxide ($2CO = CO_2 + C$). The reaction is reversible.

Belynskis Reagent. A 1% copper sulphate solution recommended as an etchant for revealing dendritic structures in high carbon steels.

Benbond. A finely ground plastic clay prepared from a deposit in Essex, used as a bond in foundry-sand mixtures.

Bench Drawn. (*Rack Drawn.*) Straight lengths of bars as bright drawn on a *draw bench.*

Bend Number. The number of reversed bends, through a specified angle (usually 90°) about a specified radius, to which a specimen can be subjected without fracture.

Bend Test. A test made on certain classes of material to determine the soundness of internal structure and to denote the degree of ductility. The test consists merely in bending a standard test specimen through a certain specified arc. Examination of the bend may disclose surface defects. For bar material, the test pieces are bent cold. Bars are bent round a pin or mandrel of a specified radius until the sides are parallel, or through a specified angle. Such tests for sheet and strip may be divided into at least two classes: (*a*) single- and (*b*) reverse-bend tests. *Single-bend tests* may again be subdivided into three classes:

(i) Bending flat over 180° (*Close Bend*).
(ii) Bending through a given included angle over a specified radius (*Angle Bend*)
(iii) Bending through 180° over a specified radius (180° Bend).

Reverse-bend tests may be sub-divided into two classes:

(i) Repeated bending through 180° over a specified radius (180° Reverse Bend).
(ii) Repeated bending through 90° over a specified radius (90° Reverse Bend). (B. 100.)

Benders. (*Setters.*) Devices used in drop forging hammer dies to bring the several sections of the stock or prepared blank into alignment.

Bending. Bending processes include:—*spinning*; hammering the metal to a formed tool; bending it around a pin or forming tool between walls; bending it about a fixed pin without walls; folding it over itself or a fixed bar or plate; holding one end firmly in a pivoting vice and preventing the movement of the free end by a fixed stop; forming the metal around a rotating mandrel or forming tool; forcing it between fixed points or walls; and rolling. (L. 43.)

Bending Rolls. Three staggered *rolls* adjusted to put the desired curvature in plate or used for coiling and uncoiling strip or wire. (A. 27.)

Bending-Tensile Test. Comprises suspending a flat test-piece (150 × 8 × 0·5 mm.) between the holders of an *Amsler machine* and applying a load at the lower end in 1 kg./mm² increments whilst the upper half of the specimen is bent to and fro over two parallel rollers through an angle of 180°. The load-elongation curve of pure metals and single-phase alloys closely resembles that of the ordinary tensile test and gives only one point of inflection, i.e. that corresponding with the yield point; that for heterogeneous alloys, on the other hand, shows two inflection points, the second corresponding with the static yield point and the first with the endurance strength in the alternating fatigue test. (B. 131.)

Bendix Method. A means of determining coating thickness on tinplate, in which the tin is removed by anodically polarizing, in hydrochloric acid containing iodine, a tinplate disc suspended by its edge from an electromagnet. Porous pots on either side of the disc enclose carbon-rod cathodes. The iodine is reduced by the tin entering the solution, and the weight of tin removed is calculated from the decrease in the iodine content of the *anolyte.* (S. 6)

Bendix Plaster Process. A *precision casting* process. (P. 26.)

Bendometer. An impact bend testing device. The specimen is clamped between two parallel jaws and a pendulum carrying the desired weight of 112 or 400 g. is released from a given angle, being allowed to strike one blow, and caught on the rebound. The reading is obtained by carefully raising the pendulum until it just contacts the specimen. (F. 5.)

Benedicks and Löfquist Method for the Determination of Inclusions. Slag grains, visible under the microscope are counted and their size es-

timated, or a simple comparison made between the specimen and arbitrarily chosen standards. Based upon this comparison, a certain slag number is then allotted to the material. (B. 41.)

Beneficiation. A broad term covering any improvement in the structure or grade of iron ore for *blast furnace* use. It covers crushing, roasting, sintering, agglomerating, and all concentration processes.

Bennek Test Piece. An impact test piece recommended for low temperature tests. The test piece is 55 mm. × 10 mm. × 8 mm. and has a rounded notch 4 mm. deep and 8 mm. diameter.

Bentonite. A highly plastic clay used as a bonding material in sand moulds. It is a weathered volcanic ash, and is marketed, crushed and air-floated, usually in 200- and 300-mesh powder. It consists mainly of silica with some alumina and smaller quantities of *iron oxide, magnesia, lime* and *alkalis*. (M. 170.)

Benzene. (C_6H_6.) *Melting point* 5° C. Boiling point 80° C. *Specific gravity* 0·879. A colourless liquid, soluble in alcohol, ether, acetone, insoluble in water. Produced from coal-tar and coke oven gas; can also be synthesized from open-chain hydro-carbons. It is the basis for benzene derivatives, and is a solvent for fats, resins, etc.; very inflammable. Benzene is the simplest member of the aromatic series of hydrocarbons.

Benzine. A solvent mixture of paraffin hydrocarbons less volatile than petrol but more so than kerosene, obtained by the fractional distillation of petroleum, it is to be distinguished from *benzene*.

Berglöf Process. A method of direct reduction of iron ore. The reduction of the ore was carried out in interchangeable containers. The ore was heated to the reduction temperature in one container, and then this container was moved into the reducing zone.

Bergman, Torbern Olaf. (1735–84.) A Swedish chemist, founder of analytical chemistry, drew distinction and explained differences between pig-iron, wrought iron, and steel.

Bergsman Micro-Hardness Tester. A testing apparatus of the static impression type in which a holder for the specimen to be tested and a test load is carried by a counter-balanced lever above an indenting body to expose the surface of the specimen to be tested, downwardly towards the point of the indenting body. The holder for the specimen and the test load is suspended by a band attached to an end surface of the balance lever which is concentric with respect to the axis of movement of the lever, so as to prevent lateral movements of the band under the swinging movements of the balance lever, the holder being guided vertically. (B. 44.)

Berthelot-Mahler Bomb Calorimeter. Apparatus for determining the calorific value of fuels according to B.S. 1016.

Berthollet, Claud Louis de. (1748–1822.) A French chemist, who discovered composition of ammonia.

Bertrand-Thiel Process. A method, applied to pig irons with abnormally high phosphorus contents, which makes use of a two period scheme of purification. In the first period, the furnace is tapped to separate the metal from the highly phosphoric slag, and the metal is then returned into the same furnace or into another basic furnace for final purification. (C. 5.)

Beryllium. (*Be.*) (*Atomic weight* 9·013. *Specific gravity* 1·82. *Melting point* 1280° C. Beryllium has a hardening effect on steel and it is claimed that the addition of 0·1% beryllium to austenitic corrosion resisting steels containing 18% chromium and 8% nickel, with 3% molybdenum, gives a Brinell hardness of 500. Copper beryllium alloys are especially suitable for the production of *non sparking tools* because of their high hardness and good thermal conductivity.

Berzelius, J. J. (1779–1848.) A Swedish chemist who originated the method of symbolizing the elements. He succeeded in isolating zirconium in 1795 and silicon in 1823, and was the discoverer of selenium and thorium.

B.E.S.A. British Engineering Standards Association, incorporated as the British Standards Institution in 1929.

Bessemer Converter. (See BESSEMER PROCESS.)

Bessemer Ladle. A steel ladle lined with refractory material and having a *stopper* and *nozzle* system of pouring, i.e. bottom pouring, as distinct from tilting the ladle. (A. 26.)

Bessemer Process. A method of producing steel in which air is blown through molten *pig iron* contained in a refractory lined pear-shaped cylindrical vessel, open at the upper end for the escape of gases, the vessel being known as a *Bessemer Converter.* The heat is produced by the oxidation of impurities silicon, manganese, and carbon, by the oxygen of the air blast, which enters through *tuyeres* which are normally situated in the bottom of the converter. In the *side blown converter* the oxidizing gases are introduced through tuyeres in the side walls of the converter near the surface of the iron bath. (See also

TROPENAS CONVERTER.) In the *acid Bessemer process*, the lining is of ganister and the phosphorus content of the pig iron remains unaltered. In the *basic Bessemer process*, the phosphorus is eliminated, and passes into the slag. Magnesia or dolomite is substituted for the acid ganister lining and lime is added to the charge before blowing begins. High phosphorus pig irons are used, and much of the heat required to maintain the fluidity of the iron is derived from the combustion of the phosphorus. The highly phosphoric slag is a valuable by-product for use as a fertilizer. The basic Bessemer process is known on the Continent as the *Thomas Process*. (See Fig. 1.)

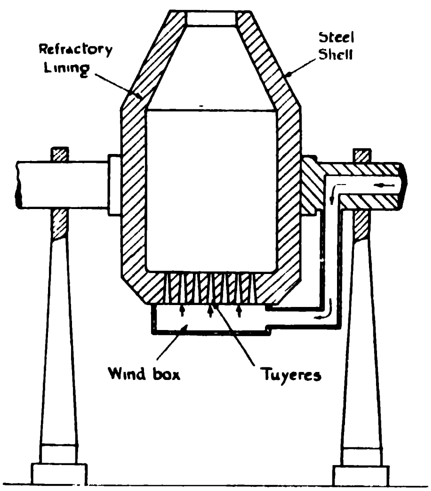

Fig. 1.—Diagrammatic cross section of Bessemer converter.

Bessemer, Sir Henry, F.R.S. (1813–98.) Born at Charlton, in Hertfordshire. Inventor of the *Bessemer process*. The discovery of the process was announced by the inventor to the British Association for the Advancement of Science in 1856. Production of Bessemer steel commenced in Sheffield in 1859.

Best Patent Steel Wire. (See PATENTED STEEL WIRE.)

Best Yorkshire. (See YORKSHIRE IRON.)

Beta Brass. A copper-zinc alloy with a copper content of approximately 54%, composed of but one type of crystals all of which are of the same composition. At ordinary temperatures, the normal range of beta brass is from 51% to 55% copper. Quenching from higher temperatures considerably broadens this range. Between 64% and 55% copper, the copper-zinc alloys consist of mixed crystals of alpha and beta, the relative proportion of which depends upon the composition and heat treatment. Alloys of this type can be mechanically worked while hot and are frequently referred to as *Muntz metal*. When rapidly cooled from high temperatures (that is, from at or near the melting point) mixed alpha and beta may occur with copper as high as 70%. (A. 28.)

Beta Iron. Non-magnetic *alpha* iron which exists between 768° and 910° C. The designation is now seldom used.

Beta Particle. An electron; one of the products emitted from the atomic nuclei of radioactive substances during their spontaneous disintegration.

Beta Radiation. A beta ray consists of a stream of electrons; it has considerable penetrating power (but less than X-rays), and can be used for measuring thickness, etc.

Beta-Ray Backscatter Thickness Gauge. This gauge measures weight per unit area of material having an appreciably different atomic number to its backing, and is used for gauging the thickness of tin coatings on steel. Similar equipment can measure plastic film on metal rollers. (I. 18.)

Betatron. A machine generating X-rays, used in industrial radiography, in which the applied voltages may be up to 100 million volts. It is stated that its radiation easily penetrates into at least 20 inches of steel.

Bethanizing. A process of zinc-coating wire. The zinc is deposited electrolytically, the wire itself being the *cathode*, while the *anodes* are a silver-lead alloy, the wire being prevented from absorbing either hydrogen or oxygen by immersion in fused caustic soda. (T. 1.)

Between Pass Anneal. A term used to signify the thermal treatment used between each cold draw pass. The usual practice is to heat to a temperature just under the lower critical and cool in still air. This treatment is used to remove stresses and to induce softness and ductility.

B/H Curve. (See MAGNETIZATION CURVE.)

B/H Loop. A closed figure formed by plotting magnetizing force against *flux density* for a magnetic material when the magnetizing force is taken through a complete cycle of increasing and decreasing values. The area of the figure is proportional to the magnetic hysteresis loss. Also called *magnetic hysteresis*, and *hysteresis curve*.

Bi. Chemical symbol for *bismuth*.

Biased Induction. (See INDUCTION, BIASED.)

Biasing Magnetizing Force. A constant, unidirectional (*D.C.*) magnetizing force superposed on an alternating (*A.C.*) magnetizing force. (A. 28.)

Biaxial Stress. A condition in which two stresses are acting in the same plane but at right angles.

B.I.C.E.R.A. British Internal Combustion Engine Research Association.

Bick-Iron. (See ANVIL.)

Bierbaum Microcharacter. A micro hardness test which measures the width of a very fine scratch produced by drawing a prepared diamond point under constant load, across the polished, or polished and etched surface of the specimen. The load may be either 3 grams or 9 grams, respectively, and the width of the scratch must be measured at magnifications of the order of 2000 diam. If the 3-gram load is used, the hardness number equals 10,000 divided by the square of the width of the scratch in microns. If the 9-gram load is used, the result is multiplied by 4 to obtain the hardness number. It is claimed that this test affords an excellent means of determining the relative hardness of microconstituents and of finely divided phases.

B.I.F. British Industries Fair.

Bill of Entry. A form, for the use of the customs, on which the merchant states the nature and value of goods.

Bill of Exchange. A document by which debts, especially foreign debts, are discharged.

Bill of Lading. A form of receipt and agreement specifying the ship's name, the shipper's name, the port of destination, the number or weight of goods, the agreed conditions concerning freight and primage, and the name of the consignee. It is given by the brokers or owners of a vessel, for goods which have been received on board.

Bill of Sight. A form entered at the custom-house, when the *bill of lading* does not give the consignee an exact description, value or quantity of unloaded goods. The goods may then be landed, and examined in the presence of an official, in order that a more exact description may be obtained.

Billet. (See BLOOM.)

Bi-Metal. Two dissimilar metals, having different coefficients of thermal expansion, fused together, into, for example, a strip, and so arranged that the strip deflects under changes in temperature. Used in electric circuits and for automatic temperature control, and, therefore, sometimes known as *thermostat metal*.

Binary Alloy. An alloy containing two principal elements.

Binder. (*a*) In the *foundry* the term is applied to the medium used to bind the sand in *sand moulding*. (*b*) In *powder metallurgy*, it refers to a cementing medium; either a substance added to the powder to increase the strength of the compact and dispelled during *sintering*, or a substance (usually a relatively low melting constituent) added to a powder mixture in order to cement together powder particles that alone would not sinter into a strong body.

Bioptix Pyrometer. (*Colour Pyrometer.*) A German optical pyrometer, which operates from the differences in colour of the heated object at different temperatures, these differences being assessed by comparison of the relative intensities of the radiation of two different wave-lengths, in the red and green respectively. For all materials which, although deficient in radiating power are constant in their emissivity factor, this ratio of intensities is unaffected by departure from black body conditions in taking the observations. Filter wedges are adjusted to make the comparison. (J. 29.)

B.I.O.S. *British Intelligence Objectives Sub-Committee.*

Birefringence. The property of an anisotropic crystal viewed under crossed nicols, whereby certain characteristic colours are produced which are a measure of the difference between the minimum and maximum values of the indices of refraction of the crystal.

Bismuth. (*Bi.*) *Atomic weight* 209. *Specific gravity* 9·72 to 9·88. *Melting point* 271°. A grey-white metallic element in the fifth group of the *periodic table*. The metal is used as a component of *fusible alloys* with lead. Bismuth has been added to corrosion-resistant chromium nickel steels of the 18/8 and 25/12 types, where in amounts of 0·1% to 0·5%, it is claimed to produce a marked increase in machinability, without impairing the resistance to corrosion. In cast iron, bismuth acts primarily as a deoxidizer, and bismuth-treated iron has been found to have more life and fluidity than ordinary iron. Bismuth also acts as a softener, and the strength of cast iron treated with bismuth is lowered as well as the Brinell hardness. (P 40.)

B.I.S.R.A. British Iron and Steel Research Association. (See Appendix V.)

Biting. A term used when the revolving rolls in a mill are trying to get a grip on the steel which is in the process of being rolled. The bite is often assisted by *ragging* the rolls.

Bitumen. A general term for petroliferous substances ranging from true petroleum through the so-called mineral tars to asphalt.

Bituminous Ores. Iron ores in which

the gangue consists principally of coaly matter, as for example, *Black band ironstone.*

Black Annealing. (*a*) *Open annealing.* A process of *annealing* without a protective medium. (*b*) The first annealing process in the manufacture of tinplate. (See WHITE ANNEALING.)

Black Ash. Impure sodium carbonate.

Black Band Ironstone. (*Wild Coal.*) An iron ore consisting of carbonate of iron mixed with coal matter. It was discovered by *David Mushet* in 1801, but is now practically exhausted.

Black Body. A theoretical thermodynamic surface which absorbs all the radiation falling on it, and therefore does not reflect or transmit any radiation. It is so called because a matt black surface is the nearest approximation to a perfect black body, which can be obtained by considering a small hole in a hollow body, the inside of the hollow being blackened and at a uniform temperature.

Black Body Optical Pyrometer. To circumvent difficulties which arise in the use of the conventional optical pyrometer in the measurement of the temperature of molten steel, due to the presence of smoke, fumes and open flames which interfere with the reading, an attachment has been designed for a *disappearing-filament* optical pyrometer. The attachment consists of four parts, (i) an adapter head, (ii) a telescopic brass tube, (iii) a stainless steel chuck, and (iv) a fused silica tube which is open at one end and closed at the other. These parts are assembled and rigidly attached to the pyrometer so that the centre line of the assembly coincides with the axis of the optical system of the pyrometer itself. Temperature measurements are taken by sighting the instrument on the internal surface of the closed end of the silica tube which is immersed in the molten steel to a depth of three to five times its internal diameter. Temperatures are read off on the unit emissivity scale of the instrument. (C. 30.)

Black Body Radiation. The quality and quantity of the radiation, depending solely on its temperature, which is emitted by an ideal *black body*, i.e. one which has no reflecting power but an absorptive power of unity. Such radiation is also emitted from the inside of a cavity.

Black Body Temperature. The temperature of a body whose emissivity is unity, or of any body under black body conditions.

Black Edges. The edges of steel strip which have become blackened during heat treatment, e.g. by oxidation or by the deposition of soot.

Black Finish. The four main types of black finishes used are: (i) Oxide coatings formed on the iron surface by oxidation; (ii) Phosphate coatings suitably stained and impregnated; (iii) Black deposits (e.g. black nickel) or coatings of other metals, such as copper, coloured black by chemical means; (iv) Black organic or enamel finishes. One simplified procedure for heat blacking consists in immersing the metal in molten sodium nitrate maintained at a temperature of about 300° C. Sometimes a mixture of sodium and potassium nitrates is employed, as this has a lower melting point than either salt alone. This method gives a greater speed and uniformity of heating, and pleasing blue colours can be obtained. Brown colours require a lower temperature and rather more skill to produce. A common procedure is to heat the parts in sand at a temperature of 240° to 260° C. The oxide finishes produced in this way are relatively thick and satisfactory. Amongst the most widely used black oxide finishes are those produced by immersion in caustic alkali solutions containing an oxidizing agent, generally a nitrate. There are a large number of proprietary processes in use based on this principle, although some of them incorporate special additions of activation agents to the alkali-oxidizing agent mixture. (S. 66.)

Black-Heart. A dark colouration sometimes seen in the interior of refractory bricks. It is caused by the vitrification of the outside of the brick before the organic substances within the brick have been completely oxidized.

Black-Heart Fractures in White Heart Malleable Cast Iron. This appears as a picture frame of ferrite crystal grains surrounding the soft black centre. The fracture is due to insufficient annealing and is caused by the presence of nodular carbon.

Black-Heart Malleable Iron. A ductile, strong, malleable iron made by the *Black-Heart Process.*

Black-Heart Process. A method of producing black-heart malleable cast iron which consists of heating *white cast iron,* which is hard, and brittle, to a temperature of about 850° for a period of days, in a non-oxidizing atmosphere. There is little decarburization. Oxidation is controlled by packing the iron in a suitable mixture of burnt and new ore so that the carbon in the outer layers only is oxidized. The iron carbide in the interior is broken down with the precipitation of graphite, rendering the castings

malleable and readily machinable, the graphite acting as a lubricant. The fracture shows a light grey outer layer, due to decarburization, and a dark grey core. (See Plate Xd.)

Black Haematite. (See PSILOMELANE.)

Black Iron Ore. (See PSILOMELANE.)

Black Light. The term popularly applied to the invisible radiant energy in that portion of the ultra violet spectrum just beyond the blue of the visible spectrum. Its wave-length is 3200 to 4000 Ångström units and it is normally generated, for example, for fluorescent inspection by mercury lamps with special filters. Black light inspection is conducted in a darkened area, i.e. no visible light present, but with either portable or flood type black light providing illumination. (B. 123.)

Black Magic. A protective treatment applied to steel in one operation. It is believed that the bath used is a concentrated alkali solution containing one or more oxidizing agents, forming a surface coating of iron oxide. The treatment is carried out at 150° C. and all steels except stainless are quickly coloured a rich blue black. (L. 48.)

Black Magnetic Rouge. A polishing material consisting of 99% Fe_3O_4.

Black Manganese. (See HAUSMANNITE.)

Black Nickel Finish. An electrodeposited coating consisting of nickel, zinc and sulphur.

Black Oxide Coating. Surface blackening stainless steels by treatment in molten dichromate at temperatures in excess of 320° C. The resulting black coating possesses a high degree of strength and elasticity, shows good resistance to wear and abrasion, improves the corrosion resistance of the parent metal in various corrosive media, does not produce any dimensional change in the treated part, and the colour is permanent. (C. 37.)

Black Oxide of Cobalt. (*Asbolite.*) (*Earthy Cobalt Wad.*) A mineral of variable composition but consisting essentially of oxides of manganese and cobalt, in some districts it may contain as much as 10% of nickel oxide.

Black Patch. An area of scale remaining after the pickling operation.

Black Pickling. The first pickling of sheets after hot rolling, by immersion in hot, dilute sulphuric or hydrochloric acid. (E. 3.)

Black Pipe. Uncoated tube which has been lacquered to give temporary protection from corrosion prior to delivery.

Black Plate. Steel plate of 12 to 32 in width produced in a tinplate mill, commonly of the acid *Bessemer* or *basic open hearth type*, obtained by cold reduction, prior to any pickling or cleaning operation.

Black Sand. Moulding sand to which *coal dust* has been added. (H. 60.)

Black Sheet. Hot rolled sheet.

Black Softened. Stainless steel sheet or strip, rolled and softened, but not yet descaled.

Black Spots. Defects noted on tin, and especially on tinned material. They consist mainly of stannous oxide and are due to an electrochemical corrosion process. (B. 88.)

Black Stains on Railway Lines. Dark streaks along the top of the rail which indicate depressed surfaces. At the depression, deposits of corrosion products accumulate, thus causing the areas to appear dark against the bright running surface of the rail. (J. 8.)

Black Strip. Strip in the as rolled condition, prior to descaling.

Black Tin. Tin oxide containing about 70% of tin metal.

Black Wash. A combination of *blacking* and *plumbago* applied as a water suspension to *mould* and *core*. It is customary to introduce a *bonding* agent such as *bentonite, fireclay, dextrine*, etc. (A. 26.)

Blackie Pyrometer. A pyrometer consisting of a series of bare wire *thermocouples* of predetermined diameters, connected differentially so that the total *e.m.f.* corresponds to the temperature that would be measured by a thermocouple of zero diameter. (B. 58.)

Blacking. A common blacking for heavy dry sand moulds is made from powdered coke mixed with *plumbago* and a binding material such as *clay wash*. *Mineral blacking* is made from gas carbon. *Imperial blacking* usually consists of a mixture of mineral blacking and plumbago. For very heavy castings a coat of hot *tar* is often applied to the moulds after they have been painted and dried. Blacking is used on *green sand moulds* and in the form of *black wash* on dry sand moulds and cores with the object of protecting the sand from the hot metal and providing a finish on the surface of the mould.

Blacking Holes. Irregular shaped surface cavities containing carbonaceous matter, found in cast iron, and usually exposed under machining operations. (I. 14.)

Blacking Scab. A casting defect caused by the flaking off of the *blacking* from the surface of the mould, due to sand expansion, the blacking being retained in or on the surface of the metal.

Blacklead. A form of graphite applied as a water suspension to skin dried moulds.

Blacksmith's Anvil. (See ANVIL.)

Blacksmith's Hearth. A refractory lined hearth at the bottom of which is a *tuyere* through which a blast of air is forced. A deep bed of coke is maintained with a minimum of blast in order to avoid burning or excessive oxidation.

Blacksmith Welding. A *forge-welding* process in which manual hammering is employed. (B. 105.)

Blank. (*a*) A term used in *powder metallurgy* to describe a pressed, presintered or fully sintered compact, usually in the unfinished condition and requiring cutting, machining or some other operation to produce the final shape. (*b*) The material of a tool or implement in a semi-finished state, e.g. a file before the teeth have been cut. (*c*) In chemical analysis, a test in which the procedure is identical with that of the actual test but in which none of the material being analysed is present. (*d*) A piece of steel of suitable weight for a specified forging.

Blank Carburizing. The carburizing procedure conducted without the carburizing medium. (B. 107.)

Blank Holder. The tool that prevents the rim of a sheet metal blank from wrinkling while it is being deep drawn. (A. 27.)

Blank Nitriding. The nitriding procedure conducted without the nitriding medium. (B. 107.)

Blank Thickness Separator. A device for producing certain types of drawn shells.

Blanking. Shearing out flat pieces of any desired shape from strip, or sheet metal.

Blast. The current of air blown into the *blast furnace* or *cupola* through the *tuyeres* for the combustion of the fuel. The blast is usually preheated in which case it is known as hot blast or if unheated as cold blast. (See also SHOT- and SAND-BLASTING.)

Blast Furnace. A tall, cylindrical, refractory lined furnace for the production of *pig iron*, and consisting essentially of five main parts: *bottom*, *hearth*, *bosh*, *stack* and *top*. The *bottom* is composed of refractory fire brick to a depth of about 15 ft. and stands on a concrete foundation; the hearth holds the accumulated molten iron and slag; the *bosh* is the widest part of the furnace and is also the area having the highest temperature; the *stack* extends from the bosh to the top and may be up to about 90 ft. in height and 20 ft. in diameter; the *top* consists of a *double bell and hopper*. A large pipe, known as the *bustle pipe*, encircles the furnace and distributes hot blast to the *tuyeres*, through which the hot blast is blown and distributed through the furnace; the tuyeres are situated below the bosh and vary in number according to the size of the furnace. The *mantle*, situated at the top of the bosh, is supported from the foundation by columns of cast iron or steel and its purpose is to support the stack and top. The gases generated during smelting are conducted from the top of the furnace through a large pipe known as the *downtake* whilst provision is made for the escape of surplus gas through *bleeders*. In operating the furnace, *iron ore*, *coke* and *limestone* are fed in at the top through the *bell and hopper*; as they descend through the furnace they

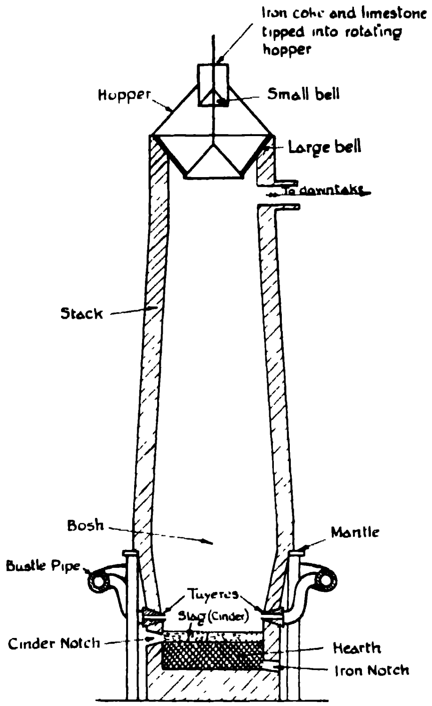

Fig. 2.—Diagrammatic cross section of blast furnace

are met by the ascending gas from the blast blown through the tuyeres. This gas in contact with the coke forms carbon monoxide which in turn reduces the iron oxide of the ore to metallic iron, the limestone forming a slag with the earthy content of the ore. (In the beginning of the campaign of the furnace, a fire is made in the hearth to provide the heat necessary to start this reaction.) The molten iron and slag thus formed trickle down the furnace and collect in the hearth, the slag floating on the top of the iron, from which they are tapped at intervals through the *iron notch* and the *cinder*

notch respectively. The operation of a blast furnace is continuous under normal conditions, but working may be temporarily suspended, by *banking*, *blowing down* or *fanning*. A furnace is closed down, e.g. for repairs to the lining, by *blowing out*. A modern blast furnace has an output of about 1200 tons of *pig iron* per day. (See also BURDEN, BURDENING THE FURNACE, BATTER, INWALLS, STOCK LINE.) (See Fig. 2.)

Blast Furnace Gas. A gaseous fuel obtained as a by-product from the *blast furnace*. Although of low calorific value, owing to its high content of carbon dioxide, it is available in large quantities and is used in preheating the *blast* and for steam raising.

Blast Gate. A sliding plate in the *cupola blast pipe* to regulate the flow of air. (A. 26.)

Blast Meter. An instrument for indicating the volume or pressure or both, of the air passing through the *blast pipe* of a *cupola*.

Blast Pipe. A pipe for conducting air under pressure. It usually refers to the section between the *blower* or *fan* and the *cupola*. (A. 26.)

Blast Pressure. The pressure of air in the *blast pipe* or *wind box* of a *cupola*, depending on the location of the indicating instrument. It is usually given in terms of ounces of water pressure.

Blast Tumbling. (See TUMBLING.)

Blast Wandering. A condition in the *blast furnace* when the *blast* fails to ascend uniformly.

Blasting. A process for cleaning or finishing metal objects by use of air blast which blows abrasive particles against the surfaces of the work pieces. (See CUT WIRE SHOT, GRIT-, SAND-, AND SHOT-BLASTING.)

Blaut Lang Process. A method of electro-polishing all grades of stainless steel. The bath is based on phosphoric and sulphuric acids. (T. 43.)

Blazed Pig Iron. High silicon *pig iron* produced during the *blowing in* of a *blast furnace*.

Blazing Off. A rough workshop method of *tempering* steel in which the steel is dipped in oil, which is then ignited.

Bleeder. (*a*) A short vertical pipe, leading from the top of the *downtake* of the *blast furnace*, which can be opened to allow surplus gas to escape. (*b*) A defect wherein a casting lacks completeness due to molten metal draining or leaking out of some part of the *mould cavity* after pouring is completed.

Bleeding. (*a*) (See RUN OUT.) (*b*) In the U.S.A. the term refers to the rising of metal caused by reactions other than those between the carbon and oxygen. Evidence has been submitted to show that the evolution of hydrogen is the primary cause of bleeding and that the addition of nickel suppresses it whilst chromium increases it. (*c*) (See FRICTION OXIDATION.) (Z. 2.)

Bleeding Ingots. Ingots lifted from the casting pit before solidification is sufficiently completed, thus causing some of the fluid centre to flow out.

Blended Moulding Sand. Mixtures of moulding sands made to produce desirable conditions.

Blending. The thorough intermingling of different batches of powder of the same substance for the purpose of adjusting the physical characteristics. (G. 30.)

Blind Pass. A *pass* in which no additional pressure is added to the rolls.

Blind Riser. An internal *riser* which does not reach the surface of the mould. It is combined with the *spingate*.

Blister. A defect caused by gas either below or on the surface of steel.

Blister Pits. Characteristic minute blisters formed under certain plating conditions in nickel or copper electrodeposits.

Blister Steel. (See CEMENTATION.)

Bloating. The swelling of a refractory article due to the formation of gases inside the material. These gases may be due to over-heating or to the presence of carbon monoxide in the furnace. (A. 26.)

Bloch Boundary. The crystal region in a ferromagnetic crystal in which the spontaneous magnetization of the crystal changes from one permissible direction to another. (B. 30.)

Block Sequence. A combined longitudinal and build-up sequence for a continuous multiple-pass weld wherein separate lengths are completely or partially built up in cross-section before intervening lengths are deposited. (See BACKSTEP SEQUENCE, LONGITUDINAL SEQUENCE.) (A. 37.)

Block Tin. A common designation for pure tin.

Blocking. (*a*) Reducing the oxygen content of the *bath* in open hearth practice by the addition of *ferrosilicon* or other deoxidizer for preventing further decrease of the carbon content and to avoid loss of alloying elements by oxidation. (*b*) The initial forging operation which imparts to the piece its rough but not exact shape.

Blocking Impression. The impression which gives the *drop forging* its general shape.

Bloom. An intermediate product which has been rolled or forged down from an *ingot* and is destined for further working into bars, sheet, tubes and forgings, etc.

It is usually square in section and more than 5 in. square, smaller sizes being known as *billets*.

Blooming Mill. A *rolling mill* used in reducing steel ingots to *blooms*, sometimes called *cogging mill* and not always distinguished from *billet* or *slab* mill. (N. 11.)

Blotter Powder. A medium used in *fluorescent penetrant inspection* to provide a blotting action which will hold the fluorescing oil on the surface adjacent to a surface imperfection, thus forming a more brilliant indication. Usually it consists of finely divided talc. Many other compounds may be used, provided they do not fluoresce of themselves.

Blow. (*a*) In a *Bessemer converter*, the product of a single charge, i.e. a cast. (*b*) The starting up of a *cupola*. (*c*) In a casting, the forcing of air through molten metal due to insufficient *venting*. (*d*) The impact or other pressure produced by the moving part of any forging unit.

Blow Gun. A valve and nozzle attached to a compressed air line to blow loose sand and dirt from a *mould* or *pattern* also to apply wet *blacking*. (A. 26.)

Blower. A machine for discharging blast into the *cupola*. Successive amounts of air are drawn in, compressed and blown out at a pressure depending upon the opposing resistance.

Blowholes. (*a*) Round or elongated smooth-walled gas-filled cavities in solid metals. They occur during solidification of the ingot when excess gas is liberated if the steel is not killed sufficiently, the steel rising in the mould and producing an ingot, honeycombed with gas cavities. They may be subcutaneous or internal. The surfaces of blow holes may be smooth, oxidized, or bright and unoxidized. Only those with bright surfaces can be welded up. A blowhole may cause a long thread or crack in rolled material. (*b*) *Gas Pocket*. A cavity in a weld caused by the entrapment of gas. (T. 18.)

Blowing. A term used to describe a *bulging* process in which the walls of a deep-drawn shell are forced outwards by means of oil or water forced into their interior.

Blowing Down. An operation employed when a *blast furnace* is being shut down or as an alternative to *banking* for temporarily suspending working. In this case the charging is stopped and the *stock* is allowed to settle with gradually decreasing blast.

Blowing Hole. The hole in a *core box* which permits the sand to enter. (See CORE BLOWING.)

Blowing In. The process of putting the *blast furnace* into operation.

Blowing Machine. (See CORE BLOWER.)

Blowing Out. The operation carried out when the campaign of a *blast furnace* is terminated. The first phase of this operation is identical with *blowing down*, but when the *stock* reaches the vicinity of the bosh the blast is stopped, the *tuyeres* are removed, the remaining stock raked out of the tuyere ports, and finally the hearth is entirely cleared out.

Blowing Plate. (See CORE BLOWER.)

Blown Casting. A steel casting containing numerous *blowholes*.

Blown Ingot. An ingot containing numerous *blowholes*.

Blown Iron. (See BESSEMER PROCESS.)

Blowpipe. (*a*) (*Cutter*). A device used in gas cutting for mixing and controlling the gases used to heat the material to be cut and for controlling and directing the oxygen jet. (*b*) A device used in gas welding for mixing and controlling the gases so as to produce a flame suitable for welding. (*c*) In a *blast furnace*, a horizontal cast iron pipe, about 5 ft. in length, which conveys the hot blast from the tuyere to the tuyere stock.

B.L.S. U.S. Bureau of Labour Statistics.

Blue Annealing. A process of softening iron-base alloys in the form of hot-rolled sheet, in which the sheet is heated in the open furnace to a temperature within the *transformation range* and cooled in air; the formation of a bluish oxide on the surface is incidental.

Blue Arrow Treatment. As *Golden Arrow Treatment*, but results in a blue coloured appearance.

Blue Asbestos. (See CROCIDOLITE.)

Blue Billy. (*Purple Ore*, *Burnt Ore*.) An iron oxide obtained as a by-product from the manufacture of sulphuric acid from iron pyrites. Owing to its high residual sulphur content, it is not desirable for use in the *blast furnace*, but it is sometimes employed for *fettling* the *puddling furnace*.

Blue Brittleness. The loss of ductility found on testing steel in the *blue heat range* which varies between about 200° C. and 400° C. according to the composition of the steel. This embrittlement is shown by the increase in maximum strength and decrease in the elongation, reduction of area and impact value. If steel is deformed at room temperatures, heated in the blue heat range, and then tested at normal temperatures, the loss of ductility is revealed by the impact test rather than by elongation. The term blue brittleness is derived from the fact that blue oxide films are formed on

polished steel within the range of temperature in question.

Blue Copperas. (See BLUE VITRIOL.)

Blue Finished Steel. (See BLUEING.)

Blue Gas. Gas formed by the action of steam on hot carbon. Such a gas consists of carbon monoxide, carbon dioxide, and hydrogen, and burns with a blue flame.

Blue Heat Range. (See BLUE BRITTLENESS.)

Blue Iron Earth. (*Vivianite.*) Hydrous ferrous phosphate.

Blue Ironstone. (See CROCIDOLITE.)

Blue John. (*Derbyshire Spar.*) Calcium fluoride (CaF_2), a type of fluorspar found only at Castleton, Derbyshire.

Blue Line Blueprint. A white-background blue line print made on iron-sensitized paper by printing from a negative of the original drawing. It is used as a *shop print.*

Blue Planished Steel. (*Russian Iron.*) Polished steel sheet subjected to a *blueing* treatment to give it a gun-barrel blue finish.

Blue Vitriol. (*Bluestone.*) (*Blue Copperas.*) Copper sulphate.

Blued Edges. The edges of sheet or strip which have become slightly oxidized during heat treatment.

Blueing. (*a*) The formation of a thin film of oxide on polished steel to improve its appearance and enhance its corrosion resistance, i.e. *blue finished steel.* Various methods are employed. Highly polished steel strip may be blued by passing through hot sand at a temperature of about 350° C., by heating in contact with charcoal at about 500° C. or by immersion in molten potassium nitrate. *Steam blueing* is effected by the action of steam at a suitable temperature. In any modification of this process, when the desired shade of blue is attained, the treated surface is rubbed with a cloth which has been dipped in sperm oil. (*b*) A heat treatment of springs after fabrication, to reduce the internal stress created by coiling and forming. (*c*) A method of colouring gun barrels by the use of a dilute acidified aqueous solution of a copper salt and a selenium compound, preferably copper chloride and selenious acid, acidified with sulphuric acid. One suitable solution consists of about 94% distilled water, 1% sulphuric acid, 1% copper chloride, 3.75% selenious acid, 0.15% wetting agent and blue colouring. (Y. 4.)

Blueprint. A blue-background print made on iron-sensitized paper by printing from an original drawing or positive intermediate. It is used as a *shop print.*

Bluestone. (See BLUE VITRIOL.)

Bluestone Test. A test as laid down b the U.S.A. Government for stainle steel dental instruments. It consists dipping the instrument in a solution 4·5% copper sulphate, 6% sulphur acid and 89·5% water, in which it mu be resistant to copper staining.

Blunging. Mixing clay with water to creamy slip.

B.M.I. Battelle Memorial Institute.

B.M.T.P. U.S. Bureau of Mines Technic Paper.

B.N.F. Adhesion Test. An inspectic test for the adhesion of electroplate coatings carried out with the aid of vibrating ball-ended hammer actuate by a fluctuating magnetic field. (P. 43

B.N.F. Jet Test. In this test an appa atus is used which delivers a jet of suitable reagent at a constant velocit on to the desired spot on the surface c the plated article. The liquid bore through the coating at a constant rat at the temperature of testing. Th thickness is obtained by a simple pr portion from the time required for pe foration. It was at first suggested tha 5% ammonium molybdate be used t detect the appearance of the steel whe the cadmium coating has been remove It has now been found that a solution c mercuric chloride in hydrochloric acid i a much more effective indicator. (C. 31.

B.N.F.M.R.A. British Non-Ferrou Metals Research Association.

Board Drop Hammer. A drop hamme worked by gravity. It is so calle because the falling parts are attache to a board.

Board of Trade. Horse Guards Avenue London, S.W.1

Board of Trade Unit. (*B.T.U.*) A uni of electrical energy equal to one *kilowat hour.*

Bob. A wheel used for polishing. It i usually composed of a solid disc o leather, felt, or similar material, but i may consist of some other substance edged with one of these materials.

Bobby. A piece of glass rod, about 9 in in length provided at one end with a rubber cap, used in the chemical laboratory to assist in removing residues from beakers, etc.

Bod. (See BOTT.)

Body. (*a*) A quality formerly associated with some of the purest brands of *Swedish iron.* The term implies outstanding reliability under strenuous conditions which cannot always be determined by direct tests, but can only be found under practical service conditions. (*b*) That portion of the tool which includes the cutting section. (*c*) (See BULB.)

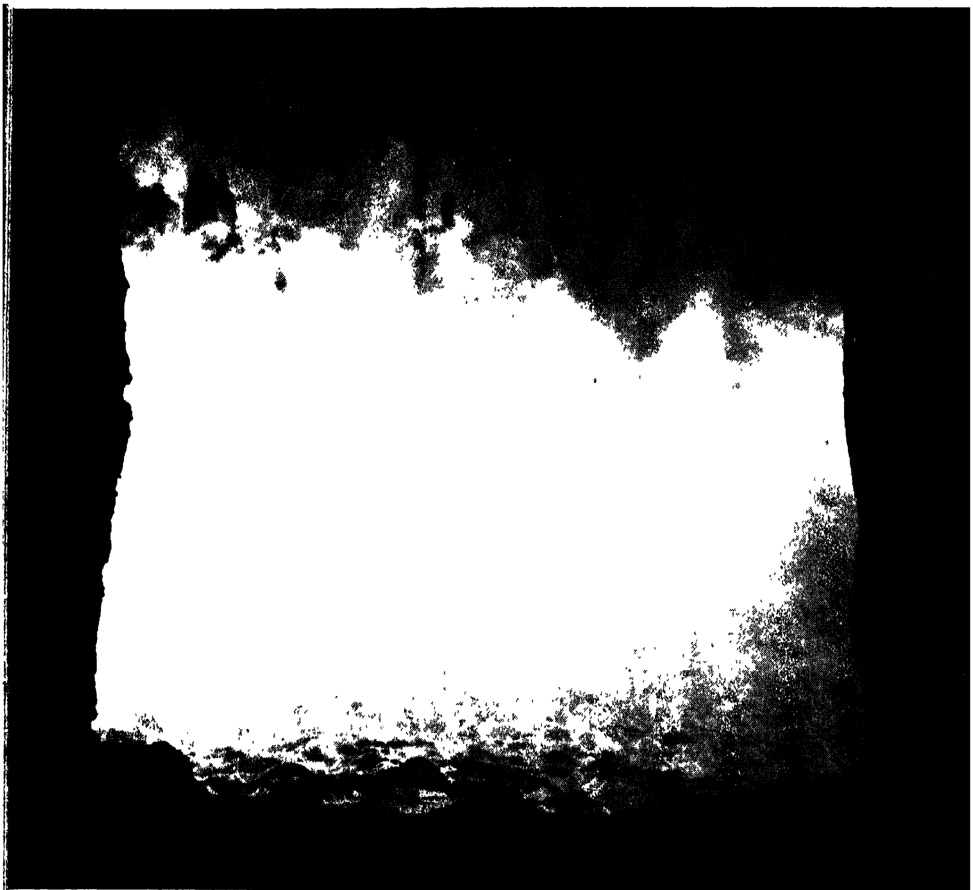

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Plate I.—"Boil" in molten steel bath as viewed through the charging door.

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Body-Centred Space Lattice. A lattice in which *atoms* are present at the corners of each cube or rectangular prism with one atom in the centre of such cube or prism. The unit cell contains two atoms, because each corner atom is shared by seven other cubes.

Boecker's Wire Mill. (See DOUBLE BELGIAN MILL.)

Boeing Method. A method of cutting stainless steel and duralumin blanks in thicknesses of about 0·04 in. A pattern for the blank or part is cut out of $\frac{3}{8}$ in. plywood and a hardened and tempered steel strip is fixed round the edge of the plywood, the edge of the steel projecting to perform the cutting operation when the sheet metal is pressed on to it. (D. 23.)

Bog Iron Ore. (*Bog Ore.*) Hydrated iron oxide, a variety of *limonite*, deposited in marshy places.

Bog Manganese. (See WAD.)

Bog Ore. (See BOG IRON ORE.)

Boil. The period after melting, in the production of steel, when, as the carbon is being oxidized, the liberated carbon monoxide gives the appearance of the metal bath being on the boil. (See Plate I.)

Boiler. A closed vessel used for generating steam or for heating water or other liquids, or into which steam is admitted for heating, steaming, boiling, or other similar purposes.

Boiler Plate. Mild steel plate, generally produced by the *open hearth process*, it is used for the shells and drums of steam boilers.

Boiler Scale. A hard coating deposited on the surface of plates and tubes in contact with water in a steam boiler. Most of this deposit is composed essentially of compounds of calcium and magnesium. Magnesium and calcium hydroxides and silicates are all found from time to time, but the most important components of boiler scales and sludges are usually calcium sulphate and carbonate.

Boiler Steel. Low carbon steel plate. (See BOILER PLATE.)

Boiling Nitric Acid Test. (See HUEY TEST.)

Boilings. The *cinder* which overflows from the *puddling furnace* during the *boil.*

Bolometer. An instrument for measuring minute quantities of radiant heat, especially in different parts of the spectrum.

Bolster. (*a*) A heavy ring into which the end of a forging can be inserted to prevent spreading. (*b*) (See BOSMENT PROCESS.)

Bolton's Reagent. An etching reagent for cast iron which contains picric acid 78 vols., nitric acid 2 vols., water 20 vols.

Bond. (*a*) Any material, other than water, which when added to moulding sand, imparts bond strength. (*b*) (*Weld Line.*) The junction of the *filler metal* and the *base metal*, or the junction of the base metal parts when filler metal is not present.

Bond Strength. The property of a moulding sand by virtue of which it offers resistance to deformation.

Bondact Process. A French process for projecting refractory material through a flexible pipe to make cupola linings, or repair old ones. It is made in two sizes projecting 25 and 50 kg. of material per minute. Driven by a ½ horsepower motor and using 3 cu.m./min., the pressure in the pipeline is 6 atm. It can also be used for ladles, annealing furnaces and kilns.

Bonderite. A zinc-iron phosphate coating for use on iron and steel, for bonding paint, and enhancing corrosion resistance. It improves the cold forming properties and facilitates drawing.

Bonderizing. A method of coating steel with manganese phosphate to increase the adhesion of paint, enamel or lacquer. The process consists of immersing the steel part in a solution of manganese phosphate and iron phosphate at a temperature of about 100° C. Further, it has been found to aid cold-forming processes in which friction is involved. The reduced friction improves tool life, increases the permissible amount and rate of deformation, and improves surface finish.

Bonderlube. A lubricant used in the cold extrusion of steel.

Bonding Clay. Any clay suitable for use as a bonding material.

Book Mould. A *mould* made in two halves and hinged at the side. (B. 12.)

Book Sizes. Approximate measurements of the boards, in inches.

Crown 8vo, 7½ × 5	Medium 8vo, 9½ × 6
Crown 4to, 10 × 7	Medium 4to, 12 × 9½
Demy 8vo, 8¾ × 5⅝	Pott 8vo, 6¼ × 4
Demy 4to, 11 × 8¾	Pott 4to, 8 × 6¼
Royal 8vo, 10 × 6¼	Foolscap 8vo, 6¾ × 4¼
Royal 4to, 12½ × 10	Foolscap 4to, 8½ × 6¾

Book Test. A test for steel plate in which a specimen of up to ½ in. gauge is folded through 180°.

Boone Wishart Fatigue Testing Machine. A rotating cantilever machine in which the specimen is loaded at the free end through a lever carrying a movable weight. (A. 35.)

Booth Hall Electric Furnace. A furnace built for working on either single-, two-phase, or three-phase current. The single-phase furnace employs an auxiliary electrode, a main electrode, a conducting hearth, and a cast steel

grid buried in the hearth. The two-phase employs two main electrodes and two grids, and the three-phase has three main electrodes and one grid. It is especially intended for melting scrap steel, from machine shop turnings to heavy scrap. The furnace is tilting and is made in five sizes from ½ ton up to 12 tons.

Bootleg. (See Box HAT.)

Borax. Sodium metaborate. It is used for coating steel rod for dry drawing, and it is claimed that it may be used as a substitute for aluminium in steel making.

Bore. The internal diameter of a rifle or gun barrel or of a tube.

Bore Lead Quenching. (See PRE-BORE QUENCHING.)

Borides. Boron combines with carbon and silicon at the temperature of the electric arc furnace to form carbon boride or silicon boride respectively. These are very hard crystalline substances which are resistant to attack by most chemical agents. Metallic borides are formed by direct union with the element at high temperatures. Borides are widely used for wear- and corrosion-resistance and it is claimed that a coating of chromium boride on corrosion-resistant valves will prevent *seizing*.

Boring. The wearing of one *tuyere* more rapidly than another in the *Bessemer Process*.

Bornand Electric Furnace. The feature of this electric melting furnace is the arrangement of a refractory body surrounding the electrodes, by which the bath may be stirred in order to speed up the chemical reactions taking place in it. In the case of a single-phase furnace, the plunger is built up as follows: A hollow-walled steel cylinder, in which cooling water can circulate, carries a number of iron bars radiating from it which form the supports for a cylindrical mass composed of magnesia and sodium silicate or magnesium chloride, the underside of the refractory material is hollowed out. After drying and baking, the block is highly refractory and very strong. The steel cylinder forms a sheath in which the electrode can slide. In order to accelerate the refining reactions, the current is cut off, the electrode control gear is put out of action, and the plunger is lowered several times into the bath; in this way the steel and slag are more intimately mixed and fresh surfaces exposed at which the reactions can occur, this being assisted by the hollow form of the lower surface of the plunger. While thus reducing the time and current required, the plunger also screens the roof from direct radiation from the arc and protects the sides of the electrode from oxidation, so effecting two further economies. The principle can of course, be equally well applied to three-phase (three-electrode) furnaces. (G. 67.)

Boron. (*B.*) *Atomic weight* 10·82. *Specific gravity* 2·3. *Melting point* 2300° C. Valency 3. A non-metallic element found in native borax and other minerals and obtained by reducing the trioxide with magnesium. It is claimed that the addition of about 0·003% of boron confers increased hardenability to steels in the quenched and tempered conditions, and boron additions up to 0·5% are claimed to give enhanced creep resistance. Further, it has been found that the addition of 0·003% boron to low carbon, 0·50% molybdenum steel in the normalized condition gives double yield strength and a 30% increase in tensile strength, but the advantage due to boron is very slight when molybdenum is less than 0·35%. However, in amounts exceeding 0·03%, boron causes hot shortness. The addition of about 0·02% to 0·10% boron to cast iron tends to inhibit graphitization and to give increased surface hardness and depth of chill. Boron additions may be made as ferro-boron, containing from about 10% to 25% boron, or in the form of an *intensifier*, a term applied to complex alloys containing in addition to boron, high percentages of other metals which serve to protect the boron from oxidation. (B. 13a.)

Boron Carbide. A carbide obtained from boron trioxide (B_2O_3) and coke at about 2500° C. It is an extremely hard material, and is used as an abrasive in cutting tools. (See also BORIDES).

Boron Nitride. Boron has two nitrides, BN with a melting point of 2730° C. and BN_2 with a melting point of 1230° C. The former is a superfine crystalline white powder of extreme refractoriness and is a non-conductor of electricity; it has good lubricating, anti-sticking and anti-wetting properties. It is claimed that sticking of molten metal with subsequent formation of skulls in ladles, etc., can be eliminated by a preliminary painting of the surface with a mixture of boron nitride and water.

Boron Trifluoride. A gaseous flux for welding steel.

Boroscope. (*Introscope.*) An instrument for the visual examination of the interior of tubes or the bores of guns or the like. It is fitted with an eyepiece at one end whilst at the other end is a tilting mirror and a light which may be extended into the bore.

Borosil. An alloy, containing 3% to 4% boron, 40% to 45% silicon and the remainder iron, used for making boron additions to the ladle.

Bort. The name for low-grade industrial diamonds or fragments of diamond which are useless as gems. They are usually pulverized and used for grinding.

Bortam. A boron-containing *master alloy* consisting of about 16% to 18% titanium, 13% to 15% aluminium, 22% to 24% manganese, 20% to 25% silicon, and 1·5% to 2·0% boron, with carbon not exceeding 1%.

Bosh. (*a*) See BLAST FURNACE. (*b*) A bath as for example, for pickling or quenching operations.

Bosment Process. A method of *teeming* in which a *bolster*, consisting of a spiral of wire netting, is placed at the bottom of the ingot mould with the object of eliminating splashing. (B. 69.)

Boss. (*a*) A projection, usually cylindrical, on a machine part, in which a shaft or pin is to be supported. (*b*) A projection on the surface of a forging.

Bosshardt Furnace. A special design of *open hearth furnace* characterized by the extremely high built-up air-uptakes at each corner, and the very steep slope of the ports. Two gas-producers are connected immediately with the furnace, having a slot opening from the level of the white-hot zone level of the producers directly into the furnace hearth. This effects an early ignition of the gas and a very high temperature in the furnace. The air is pre-heated in the usual regenerative chambers. (M. 13.)

Bosshead. A device used with a retort stand for fastening a clamp on to the stand. It possesses two jaws, one of which grips the stand whilst the other grips the arm of the clamp.

B.O.T. *Board of Trade.*

Bott. (*Bod.*) (*a*) In *cupola* practice, a chunk of clay stuck on the end of a *stopping bar* and used to stop the flow of metal from the *cupola*. (*b*) In *blast furnace* practice, a short iron rod, tapered to fit the *monkey* and attached to a long steel rod which serves as a handle, used to stop the flow of *slag* from the *cinder notch*.

Bott Stick. (*Stopping Bar.*) An iron rod with a loop or long wooden handle at one end and a small round disc at the other, to receive the *bott*.

Bottling. The operation of reducing the internal diameter at the end of a hollow forging.

Bottom Board. The board on which the *mould* rests in *sand moulding*.

Bottom Casting. (See UPHILL CASTING.)

Bottom Gate. The channel so positioned in the *runner* that it allows the molten metal to flow to the bottom of the mould.

Bottom Plate. (*a*) The cast iron plate upon which an open-ended ingot mould is placed. (*b*) The loose plate placed into the bottom of the mould to receive the first impact of the stream of molten steel from the ladle.

Bottom Pouring. (*a*) For the meaning of the term as applied to ingots see UPHILL CASTING. (*b*) The filling of a mould from the bottom by means of gates from the runner. (A. 26.)

Bottom Pouring Ladle. The normal *ladle* used in steel making practice in which the molten steel, controlled by a stopper, flows through the nozzle in the bottom of the ladle. It is so described when distinguishing it from a *lip pouring ladle* which is discharged by tilting and allowing the metal to flow over the lip.

Bottom Running. (See BOTTOM POURING.)

Bottom Splash. (See DOUBLE SKIN.)

B.O.T.U. The Board of Trade Units of energy (*B.T.U.*) or the *kilowatt hour*.

Bouncing Ball Test. A workshop method of measuring hardness in which a hardened steel ball (e.g. a ball bearing) is allowed to drop down a glass tube on to the material to be tested. The tube is graduated by file marks at equidistant points and before use is calibrated against specimens of known hardness. (J. 20.)

Boundary Wave Length. The shortest wave length in an X-ray spectrum.

Bourcoud Process. Bourcoud has proposed two processes, for the direct production of iron from ore. In the earlier process, the ore was reduced by circulating gas in a shaft, the lower part of which was arranged as an electric furnace to melt the sponge. The gas issuing from the top of the reduction shaft was pumped into a heater, where it was heated up to 1200° C. It then passed into a shaft filled with glowing charcoal, which converted the CO_2 into CO. This reaction being endothermic, the gas was again heated up to 1200° C. before being returned to the reduction furnace. In the second process, the reduction is carried out with gas prepared from powdered coal and pre-heated air in a specially constructed producer. The gas enters the reducing chamber at a temperature of about 1000° C. The ore is pre-heated before entering the reduction furnace, the temperature at entrance being 700° to 750° C. The reducing chamber is a rotary furnace of special design. The furnace is built

with an inner spiral wall, which causes an increased intensity of impact of the gas on the ore, giving a much more efficient reduction of the ore than in the blast furnace. The reduced metal in the form of sponge, is continuously discharged, compressed and passed into an electric melting furnace, which works at a temperature only high enough to separate the slag from the molten iron. Part of the gas issuing from the reduction furnace is used to heat the preheating furnace and the heater for the air for the producer.

B.O.V. Brown oil of vitriol (77% H_2SO_4 by weight).

Bow. (See CAMBER.)

Bower-Barff Process. In this process the steel is heated to about 800° C. for twenty minutes, first in contact with air and then in superheated steam. A coating consisting of a mixture of Fe_2O_3 and Fe_3O_4 is formed, after which heating is continued in a producer gas atmosphere which converts the coating entirely to Fe_3O_4. This coating is said to have high durability owing to the fact that both the underlying metal and the oxide have similar coefficients of expansion. (S. 66.)

Box Annealing. (*Close-*, *Coffin-*, *Pack-* or *Pot Annealing*). This process consists of heating *en masse* a block of sheets resting on a metal bed under a heavy metal cover, sand being placed in the bottom to prevent the entry of the products of combustion. These boxes rest on heavy bogies, and are pulled through the preheating, heating and cooling zones of a long furnace, they are often drawn at a red scaling heat. The time necessary is very variable; occasionally less than 24 hours, but often 3 to 4 days, are required for the furnace cycle. (W. 43.)

Box Carburizing. (See CARBURIZATION.)

Box-Hats Ingots. (*Boot-leg*, *Top-Hat*, *Receding Metal.*) So-called box-hat ingots are of accidental occurrence and are to be found in practice only during the manufacture of low-carbon steels where the ratio of FeO to carbon is particularly high. The box-hat is formed by a decrease in the ebullition of gas after teeming has ceased. The volume occupied by the gas bubbles in the molten ingot when the ladle is withdrawn decreases, with the result that the molten steel sinks below the original level in the *mould*. A vertical section usually discloses a thick rim free from *blowholes*, tapering from the final to the original level occupied by the steel. Ingots teemed subsequently may be rectified by the addition of a few chips of aluminium to the mould, or by the addition of a few blocks of aluminium to the *ladle*. (I. 78.)

Box Pass. A rectangular pass in which the sides are parallel to the axis of the roll and to the radii.

Box Pile. A pile, the outside of which is formed of flat bars and the interior of a number of small bars, all bars running the full length of the pile. The term is used in the manufacture of *wrought iron* bars. (A. 28.)

Box Pin. (See FLASK.)

Boyle, The Hon. Robert. (1627–91.) An English scientist who gave the modern definition of an element and enunciated *Boyle's Law*.

Boyle's Law. The volume occupied by a given mass of any gas at constant temperature varies, within moderate ranges of pressure, inversely as the pressure to which it is subjected.

Boylston's Reagent. A 5% solution of nitric acid in absolute ethyl or methyl alcohol, used for the general etching of normal carbon steels.

Br. Chemical symbol for *bromine*.

Brace Clad Process. This process consists of laminating a layer of silver brazing alloy to one or both sides of such metals as copper, most types of brass, all types of nickel silver, and monel, etc., the silver brazing alloy being diffused into the parent metal. (S. 131.)

Brackebuschite. ($2(Pb,Mn,Fe)O.V_2O_5.H_2O$.) A vanadium ore.

Brackelsberg Furnace. This consists of a cylindrical steel shell with a refractory lining. It is open at both ends and rotates mechanically on its axis at about 1 r.p.m. It can be tilted both for charging and for slagging, the movements being electrically controlled. It is fired with pulverized coal. The capacity is usually not less than 5 tons. (C. 49.)

Brackelsberg Process. A process by which fine ores are moistened with water to which a binding medium is added and the wet mass, without any heating, is rotated in a drum till it forms into spherical lumps of varying size. The moisture is then dried out by evaporation and the product remains in the form of hard and very porous balls of ore which are of great reducibility as compared with sintered ore or briquettes. (S. 99.)

Bragg Equation. (See X-RAY FLUOROSCOPY.)

Bragg Method. (For X-ray or crystal analysis.) A method using monochromatic or polychromatic X-rays and a single crystal of large size rotated through a small angle about an axis lying in a crystal face. (A. 27.)

Brale. A sphero-conical diamond indenter having an angle of 120°, used in hardness tests. It is now officially designated as penetrator C in the *Rockwell hardness test*.

Branded. The term used in relation to a roll pass when it has a name or other mark cut into it in order to leave the imprint on the finished product. The operation is known as *branding*.

Branding. (See BRANDED.)

Brandt, G. (1694–1768.) A Swedish chemist, who discovered cobalt (1733).

Brasque. To line with an inactive material.

Brass. A copper-zinc alloy of varying proportions. It usually contains more than 18% zinc; lead is sometimes added in amounts up to 2%. A typical brass contains 67% copper, and 33% zinc. (See also ALPHA BRASS and ALPHA BETA BRASS.)

Brassert Process. (*a*) A method for the elimination of excess sulphur by the addition to the ladle or mixer of a predetermined quantity of sodium carbonate. (*b*) A method for the production of *sponge iron* in which coke-oven gas is used as the source of hydrogen. The coke-oven gas is desulphurized, preheated to 650° to 700° C. and passed into the bottom of a vertical *Herreshof furnace* into which the ore is fed at the top. In this furnace the finely divided ore passes down over a series of disc plates to the slotted grate at the bottom, through which the hydrogen passes upwards. By bubbling the gas through the fine ore the latter is made to flow along channels and from one plate to another as if it were liquid. To prevent reoxidation of the hot reduced fines they are passed directly to a briquetting press.

Braunite. An important ore of manganese. It is essentially an oxide of manganese and silicon and may contain about 10% of the latter element.

Brazing. A process of joining metals by means of a lower melting point alloy deposited between closely adjacent surfaces of the parts to be joined. In general, the melting point of the brazing filler metal is above 500° C. but still below that of the metal being brazed.

Brazing Solders. Alloys used for *brazing*. They include copper-zinc (49% to 55% copper), copper-zinc-silver (16% to 52% copper, 4% to 38% zinc and 10% to 18% silver), also nickel-silver alloys.

Brazing Spelter. (See SPELTER SOLDER.)

Break Out. (*a*) The escape of molten metal from the furnace. (*b*) The appearance of the flame at the mouth of the *Bessemer converter* when the carbon begins to burn.

Breaking Down. (*a*) The operation of hot-rolling sheet bars down to a gauge of about ⅛ in. (*b*) The first stage in the cold rolling of hot-rolled strip designed to reduce its thickness. The strip is then annealed, followed by the operation of *getting down*.

Breaking Load. The load acting on a specimen at the moment of fracture. In the *tensile test* the breaking load is less than the *maximum strength*, because necking decreases the area under tension.

Brearley, Harry. (1871–1948.) A Sheffield metallurgist who, in 1913, whilst carrying out a research on gun steels in the Brown-Firth Research Laboratories, Sheffield, discovered the corrosion-resistant properties of stainless cutlery steels of the type containing approximately 0·30% carbon and 12% to 14% chromium.

Breast. (*a*) The clay put into the opening, above the spout of the *cupola*, to form the *tap hole*. (*b*) The front bank of an open hearth furnace. (*c*) The working face of a mineral deposit.

Breeze. Fine coke of ⅜ in. and under. (See COKE BREEZE.)

Brenner Magne-Gauge. An instrument for the measurement of coating thickness. It employs a sensitive spring balance to measure the force required to withdraw a permanent magnet from the surface of the coated article. The instrument may be calibrated to indicate coating thickness, since the thinner the coating the greater will be the force necessary to effect separation. (L. 37.)

Brenner Microhardness Tester. An apparatus for measuring the hardness of electrodeposited coatings at temperatures up to 900° in an inert atmosphere. Coatings thicker than about 0·07 mm. can be tested. The main parts of the apparatus consist of: (1) an indenting mechanism consisting of a Vickers' diamond, mounted on a shaft of fused silica; (2) a mechanical device for raising and lowering the indenter; (3) a micrometer device for orienting the specimen under the indenter; and (4) a heating unit. The force on the indenter can be varied either by deadweight loading or by changing the gas pressure inside the apparatus. (B. 87.)

Breunnerite. (See MAGNESITE.)

Brick Inclusions. Pieces of broken runner brick and ganister embedded in the ingot surface. Although sometimes difficult to see, as only a very small part may be visible, if such a spot is chipped, an inclusion of considerable size may be found.

Bricking Up. An operation which has to be carried out during the reheating of a large forging if a part of the ingot

or forging projects from the front of the furnace. The door of the furnace is then lowered on to it leaving an opening at each side and the opening is filled with a loose wall of fire bricks, the bricks being lifted into position by long bars with flattened ends known as *paddles*. The wall or *stopper* so built is then *clayed up* by throwing on handfuls of "clay" which actually consists of a mixture of old fire bricks and fireclay, which has been ground up and made just wet enough to handle. (B. 42a.)

Bridge Disc Weld. A single resistance *weld* whereby an overlapping disc is attached to two parts butted together. The area of the weld depends upon the size of contact point used and may be less than the area of the disc. The sizes and pitch of the disc should be specified. (B. 105.)

Bridge Seam Weld. A *seam weld* made by the resistance seam-welding process, where a strap is placed longitudinally over a *butt joint* and welded progressively to the parts. (B. 105.)

Bridge Spot Weld. A pair of resistance *spot welds* whereby an over-lapping button or tie piece is attached to each of two parts butted together. The joint is sometimes termed a *Tie Weld*. (B. 105.)

Bridging. (*a*) (*Scaffolding*). In a *blast furnace*, sticking or arching of fine ore against the walls, preventing the descent of the charge. (*b*) A similar phenomenon in a *cupola* furnace. (*c*) In an *electric furnace*, formation of a bridge by the upper layers of scrap over the pool of steel. (*d*) In the foundry, local freezing across a mould before the metal solidifies. (*e*) A defect found in ingots when the metal solidifies below the head. Below this solid portion, unsoundness again appears, this being usually termed *secondary pipe*. (*f*) In powder metallurgy, the formation of arched cavities in a powder mass which may result in voids or uneven density in a *compact*, or which may result in stoppage or interruption of flow of powder through a funnel or other feeding device.

Bright Annealed Wire. (See WHITE ANNEALED WIRE.)

Bright Annealing. A process of annealing which is usually carried out in a controlled furnace atmosphere (i.e. non-oxidizing), so that surface oxidation is reduced to a minimum and the surface remains relatively bright. (M. 78.)

Bright Bar. (See BRIGHT STEEL BARS.)

Bright Dip. A solution consisting of an acid or a mixture of acids into which articles are dipped to produce a bright clean surface, on mild and medium carbon or alloy steels. The surface so obtained is not a mirror finish.

Bright Drawing. Decreasing the diameter of a hot-rolled descaled bar by pulling in the cold through a hole of the desired finished size in a specially prepared die. Bars drawn in this way have a bright smooth finish and the sizes can be kept within very close tolerances.

Bright Drawn Bars. (*Cold Drawn Bars*.) (See BRIGHT DRAWING.)

Bright Ground. Steel bar which has been *centreless ground* by passing through abrasive rolls whose axes are parallel to the work.

Bright Machined. Steel which has been ground, milled, shaped, or turned to size to produce a smooth bright surface finish.

Bright Steel Bars. Steel bars treated by mechanical means to have a scale-free, smooth and bright surface, giving optimum machinability, and accuracy of dimensions and section. They may be produced from hot rolled bars by any of the following processes: *Bright* (or *Cold*) *Drawing, Bright Turning Centreless Grinding, Cold Rolling*. They may be manufactured by other machining operations, such as *planing* or *milling*, but such methods are exceptional. (B. 99.)

Bright Turning. A process in which round, hot-rolled bars are reduced to the required size either by lathe turning between centres, or by passing through a centreless bar turning machine, in which one or more circular cutter heads revolve. The resulting bar may then be *cold-rolled* to remove tool marks.

Brightener. Material added to an electroplating bath to give the deposited metal a highly reflective surface. (A. 27.)

Brinell Hardness Number. (See BRINELL HARDNESS TEST.)

Brinell Hardness Test. The test consists of indenting the metal with a 10 mm. diameter steel ball subjected to a load of 3,000 kg. For soft metals, the load is reduced to 500 kg. to avoid too deep an indentation. The load is applied for 30 seconds, after which it is removed; the diameter of the recovered indentation is measured and the Brinell hardness number calculated by dividing the load applied by the surface area of the indentation. Various types of machine are used for this test but the most common is of the hydraulic type.

Brinell, J. A. (1849–1925.) A Swedish engineer and Bessemer Gold Medallist. He carried out many investigations on the heat treatment of steel but is most widely known as the originator of the

method of testing the hardness of steel to which he gave his name.

Brinell Meter. A 10 mm. hardened steel ball is held in a hammer-like frame and is backed up by a bar of known hardness. The sample is struck a sharp blow by this assembly and the resulting indentations (made by the ball) in the bar of known hardness and specimen are compared. With the aid of a table, the hardness of the unknown is determined. (W. 14.)

Brinell Pliers. A portable hardness testing device in the form of nippers. Various modifications of these pliers have been designed, e.g. the *Stanfield Hardness Tester*, and the *Rudge-Whitworth Pliers*.

Brinrock Number. A hardness value obtained as follows:

Brinell ball number $\frac{L}{\pi Dh}$, where h is the depth of the impression.

Then Brinrock number =

$$\frac{\text{total load (60)} - \text{constant minor load (10)}}{\pi \times 3{\cdot}175 \times (100 - \text{"C" scale reading} \times 0{\cdot}002)}$$

when using $\frac{1}{8}$ in. (3·175 mm.) ball and the 60 kg. loading (O.9).

Briquette. (See COMPACT.)

Briro Hardness Tester. A German Brinell Rockwell instrument with tension holding arrangement, in which the work is held under a pressure of 10 kg. with loads up to 1,000 kg., or under a pressure of 250 kg. with loads up to 3,000 kg. In another type, the dial gauge is dispensed with and only the testing loads of 250 to 750 kg., respectively, are indicated. (R. 25.)

Britannia Metal. An alloy of from 74% to 91% tin, 6% to 24% antimony, and 0·15% to 3·68% copper, sometimes with small quantities of zinc, lead and bismuth. A Britannia metal containing 90% tin, and 10% antimony has a specific gravity of 7·9 and melts at 260° C. Formerly it was extensively used in the manufacture of cheap tableware, such as teapots and spoons, also as an antifriction metal.

British Basic Irons. Grades of pig iron which normally contain about 1% phosphorus, 1% silicon and 1% manganese.

British Intelligence Objectives Sub-Committee. (*B.I.O.S.*) This subcommittee was responsible for the issue of reports prepared by the teams of British and U.S.A. experts following their inspection of German and Japanese industrial concerns in the period immediately following the end of World War II. These reports are now on sale at the Technical Information and Documents Unit, 15 Regent Street, London, S.W.1.

British Non-Ferrous Metals Research Association Micro-Hardness Tester. The apparatus uses a square based diamond pyramid indenter with the faces of the pyramid worked to an angle of 136° as in the standard Vickers machine. The diamond supports the weight of the head and plunger. The minimum total load applied is 16·85 gm.; the load can be increased by placing small known weights in the interior of the plunger. The breaking of an electrical circuit is taken as an indication that the load is applied to the diamond. (P. 17.)

British Non-Ferrous Metals Research Association Rotating-Load Fatigue Testing Machine. A high-temperature fatigue-testing machine in which the principle of operation is a modification of the normal Wöhler test in which a rotating cantilever specimen is subjected to a constant bending moment, the material at any point of the specimen being subjected to equal and opposite stresses during each cycle. In the rotating-load machine one end of the cantilever specimen is held stationary and a constant-value rotating bending moment applied by means of a rotating out-of-balance mass at the other end. A stationary specimen permits accurate measurement of temperature to be made by a thermocouple in intimate contact with the section at maximum stress. (M. 12.)

British Standard Wire Gauge. (*S.W.G.*) A series of numbers used to express the diameter of wires.

British Thermal Unit. (*B.Th.U.*) The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit (60° to 61° F.).

Brittle. Lacking ductility. A material which ruptures without undergoing any plastic deformation is absolutely brittle, but the term is used in a relative sense to describe the tendency to break under shock or stress, without any appreciable deformation. This should be distinguished from *notch brittleness* as shown by the *notched bar test* where section and conditions act as *stress raisers* which materially affect the result.

Brittle Coating. (See BRITTLE LACQUER METHOD.)

Brittle Fracture. (See FRACTURE.)

Brittle Lacquer Method. A technique which may be used either for (*a*) the rapid survey of structures for stresses resulting from externally applied loads or (*b*) for the study of residual stresses. In either case the part is first coated

with lacquer which is allowed to dry thoroughly. In one form of (*a*) the test employs a steel strip 12 × 1 × ¼ in. as a cantilever beam held at one end of a stand by an adjustment screw which lifts the other end of the strip against a cam designed to apply a known deflection load. This deflection is such that the upper surface of the coating on the strip will exhibit varying amounts of strain when pressure is applied. Strain patterns in the form of closely spaced lines across the strip appear in the coating when the load is applied. The strip is released and placed against the scale from which the amount of strain is read. (F. 24.) In (*b*) a hole not over ⅛ in. diam, is drilled in the specimen to a depth of $\frac{1}{16}$ to ⅛ in. at each check point. The relaxation of the residual stress about each hole brings out a crack pattern characteristic of the type of stress existing in the area. (See also STRESS COAT DRILLING.)

Briviskop. A hardness testing machine. The characteristic feature is the projection equipment which is integral with a swing-out type indenter, this being so arranged that the indenter automatically swings forward upon release of the load, thus leaving the impression in the field of view of a microscope. A magnified image of the impression is projected on to a glass screen on the machine head by a reflected beam of light. Measuring is by means of a micrometer adjusted sliding scale fitted over the screen. This is graduated in tenths and hundredths of a millimetre, whilst the micrometer provides readings of thousandths and ten thousandths millimetre on the larger and smaller machines respectively.

Brivisor. A hardness testing machine designed as single purpose equipment for use with either Brinell or Vickers tests. The size of the impression is read by moving the microscope, the amount of movement being indicated by a dial gauge method mounted on the head. From a conversion table the Brinell or Vickers number corresponding to the dial readings can be found.

Broach. A tool consisting of a series of cutting teeth so arranged that each cutting surface removes a predetermined amount of material. Each successive cutting surface extends slightly beyond the preceding one, determining the chip load per tooth. The first section of the broach cutter contains teeth designed for the heavy roughing cut to remove excess material, whilst the last section contains the finishing teeth which accurately size the workpiece and produce a fine finish. (K. 25.)

Broaching. The operation of smooth machining holes in castings or forgings by drawing or pushing one or more *broaches* through the already rough cored or drilled hole.

Broemel Strip Mill. The principal characteristic of the Broemel Patent is the introduction of reheating furnaces between the rolling mill stands. (T. 27.)

Broken Back. (*Cracked Back.*) A defect in drawn wire which takes the form of a band of transverse cracks along its length.

Bromine. (*Br.*) *Atomic weight* 79·916. *Specific gravity* 3·12. Boiling point 58·78. One of the halogens. A non-metallic element which at normal temperatures is a dark red liquid giving off a dark red poisonous and irritating vapour Br_2. It is chemically reactive and has considerable use for bleaching and other purposes.

Bronze. An alloy of copper and tin in varying proportions. Other elements such as zinc, nickel, phosphorus, aluminium and lead are often added, e.g. *phosphor-bronze* and *gun metal*. Lead up to 2% is often added to produce cleaner castings and to improve the machining properties. The presence of zinc facilitates casting and up to 5% is added for statuary.

Bronze Welding. A method of joining metals or alloys with melting points above 875° C. A copper-zinc alloy rod and a non-fusion gas welding technique are employed to produce strong, ductile joints in both ferrous and non-ferrous metals. Effective preliminary cleaning of the work is essential for a sound joint, which is further assured by applying the flux beforehand as a paste. A slightly oxidizing, oxy-acetylene flame, smaller than for *fusion welding*, is used, the operating temperature being about 925° C. (P. 2.)

Bronzing. A method of producing a bronze coloured iron oxide coating on steel. The steel article is exposed to the vapour of a mixture of hydrochloric and nitric acids for a period of up to 5 minutes and then heated to a temperature of 300° to 350° C. until a bronze colour appears. The part is then cooled and rubbed with petroleum jelly and again reheated to decompose the petroleum jelly. Finally, it is again treated with the petroleum jelly or oil. The treatment gives increased resistance to corrosion and wear.

Brosius Electric Blast-Furnace Tap-Hole Stopping Machine. The machine consists essentially of a clay barrel fitted with a nozzle and containing a piston, the rod of which embodies a double rack driven by two pinions. (E. 45.)

Brown-Firth Photo Electric Pyrometer. A pyrometer developed in the Brown-Firth Research Laboratories which measures the radiation from a hot body by means of a *caesium vacuum cell*. It has been designed primarily to measure the temperature of high speed steel being heated by high-frequency induction. An image of the hot body is formed on an etched screen, with a hole in it, by a convex lens. This image is focused by viewing it through a plane mirror. Just behind the screen is a disc, which is divided into 16 sectors with the alternate ones cut out so that, when the disc is rotating at about 25 r.p.s., it interrupts the radiation at a frequency of 200 cycles/second. In this way, the cell output, which normally would be insufficient to work an indicator or relay directly, can be amplified by a stable audio-frequency amplifier of high gain. (S. 140.)

Brown-Firth Tester. (See STANFIELD HARDNESS TESTER.)

Brown Haematite. A type of *limonite*.

Brown Ironstone. A type of *limonite*.

Brown and Sharpe Wire Gauge. An American system of designating the diameters of wires in numbers.

Browning. (See BRONZING.)

Brown's Test. A method of testing the wear on a wire rope. The wear on the rope is effected by passing a loaded roller over it under pressure.

Brownsdon Tear Length Test. (See TEAR LENGTH TEST.)

B.R.R.A. British Refractories Research Association.

Bruising. (*a*) Injury to the ingot skin, e.g. *dog marks* or indentations caused by the dropping of the hot ingot against some sharp object. (*b*) Surface damage to a steel product caused by the dropping of tools, etc., which results in local changes in the geometry of the surface and a highly localized state of residual stress due to the plastic deformations involved.

Brunofix. A proprietary process for the production of a black oxide coating on steel by immersion in an alkaline solution to which has been added an oxidizing agent.

Brunorizing. The trade name for a special treatment applied to steel rails which, after cooling to a temperature below the transformation range, are reheated to a temperature slightly above that range, and then are allowed to cool in air, the ends of the rails being partially quenched by jets of compressed air. (B. 60.)

Brushing. A surface finishing operation in which *laps* are replaced by fibre brushes and a special polishing compound is applied to the brushes. Brush polishing is stated to produce a satisfactory satin finish.

Brutonizing. A method of rust proofing wire by hot *galvanizing*.

Bryanizing. A method of *electro-galvanizing wire*. It is claimed to give very high resistance to corrosion owing to the excellent bonding, the uniformity of thickness, and the purity of the electro-coating.

BRYlanizing. An electrolytic method of coating wire with zinc.

B.S.F.A. British Steel Founders Association.

B.S.I. British Standards Institution.

B.S.M. Bureau of Steel Manufacturers, Australia.

B.S.R.A. British Shipbuilding Research Association.

B.Th.U. (See BRITISH THERMAL UNIT.)

Bubble Hearth Furnace. A furnace intended for the direct production of sponge iron, in which the iron ore was reduced by bubbling hydrogen through it from inlets resembling the bubble caps used in fractionating towers. The process was not successful. (B. 18.)

Buckle. (*a*) Swelling in the surface of a *mould* due to the generation of steam below the surface. (*b*) The indentation in the casting produced by this swelling.

Buckle and Kink. A corrugated or wrinkled surface condition caused either by worn-out pinions on a roll stand or uneven cooling beds. Buckle is an up-and-down wrinkle, whereas kink is a side wrinkle.

Buckling. (*a*) The bending of sheets or plates under a compressive load. (*b*) A weld defect caused by the heat of the arc resulting in distortion at the point of working due to locked up stresses, the cooling effect of air currents and the tendency of light gauge sheets to distort when subjected to high temperatures. (*c*) The effect produced when one part of a rolled bar tends to have a greater length in the direction of rolling than another.

Buckshot. A term applied to particles of iron trapped in *blast furnace* slag.

Budd Induction Hardening. In this process the *Hi-Electro* heat treating machine hardens the inside diameters of cast iron liners to a surface hardness of 52 to 55 Rc, which is subsequently tempered to a slightly lower hardness. The depth of the hardened area developed is approximately 0·070 in. Differential hardening by electromagnetic induction is accomplished through the concentration of high power, high frequency currents in the surface zone to be hardened so that the temperature of

the zone affected is raised to hardening temperature before any substantial amount of heat can drift to the remainder of the piece. Then there is an immediate application of a controlled water quench. Following the operation of hardening and tempering, the bores are honed to the final finish, before *Surfiding*, after which the outside diameter is finish turned for insertion into the cylinder blocks. (I. 28.)

Budd McKay Machine. A roller levelling machine for eliminating *stretcher strains*, the sheets in their passage through this machine being subjected to double bending or flexing. (K. 35.)

Budd Shot Welding. (See SHOTWELD.)

Buffer Capacity. The amount of an acid or alkali of some definite concentration which must be added to produce change in hydrogen ion concentration represented by 1 pH unit. (B. 114.)

Buffer Reagent. A substance or a mixture of substances which, when present in a solution, tends to resist changes in the concentration of a given ion, e.g. a weak acid or the salt of a weak acid, which tends to diminish fluctuation in hydrogen-ion concentration. (B. 103.)

Buffered Water. Water containing dissolved or suspended matter which resists changes in the pH value of the water.

Buffing. The operation of smoothing a metal surface by means of flexible wheels, to the surface of which fine abrasive particles are applied, usually in the form of a plastic composition or paste.

Build-Up Sequence. The order in which the weld beads of a multiple pass weld are deposited with respect to the cross section of the joint. (See BLOCK SEQUENCE, LONGITUDINAL SEQUENCE.)

Building Up. The formation by electrodeposition metal spraying or welding of a comparatively thick adherent coating of a metal on worn or undersized machine parts in order to bring them up to the required dimensions. Such deposits may be machined if necessary. (See also HARD FACING.)

Built Up Plate. A *pattern plate* with the *cope* pattern mounted on or attached to one side and the *drag* pattern on the other. (A. 26.)

Bulb. In an X-ray tube, the part made of glass or other pressure-tight material; when made of metal it is more usually called the *body*. (A. 27.)

Bulge Test. A method of testing the drawability or bi-axial strength of sheet metal. A circular disc of 14 in. diam. is held down around its circumference by a ring, and the test region bulged by oil pressure until rupture of the sheet occurs. The amount of stretch in the upper region of the bulge after bursting, is taken as the uniform elongation. The test is similar to the *Erichsen* and *Olsen Cup Tests* but the diam. of the material under test is much larger. It is claimed that the bulge test shows up discrepancies in materials where the Olsen test fails so to do. (E. 78.)

Bulging. A process of shaping the wall of a parallel sided deep-drawn shell. Bulging by means of rubber consists of inserting the shell in a split die of the desired contour, placing inside the shell one or more pieces of rubber and compressing this by means of a punch attached to a press. In *expanding*, it is usual to employ metal tools instead of rubber to force the walls of the shell against the interior surface of a split die.

Bulk Modulus. (See VOLUMETRIC MODULUS OF ELASTICITY.)

Bull Block. A wire drawing machine consisting essentially of a power driven capstan and a single die stand. Bull blocks drawing through two dies have been developed, the capstan having two diameters to correspond approximately with the elongation of the material at the second die; these machines are known as *double deck blocks*.

Bull Dog. Roasted tap cinder consisting of ferric oxide and silica, derived from the puddling furnace. It is a refractory material and is used for fettling the *puddling furnace*.

Bull Ladle. A two-man ladle for carrying and pouring molten metal.

Bullard-Dunn Process. An electrolytic descaling and tinplating process, in which the work is made cathodic, using a high current density at low voltage in a bath containing dilute sulphuric acid and a tin salt as inhibitor. As soon as the scale or oxide is removed, a fine layer of tin is deposited in its place. This has been found to be most useful in protecting the work after cleaning and although the tin plating may be removed afterwards, if required, it has been found beneficial to retain it as a base for subsequent hot-tinning or painting. (T. 28.)

Buller's Rings. Temperature indicators consisting of rings of specified dimensions made from special unfired clay. On being subjected to heat, contraction of the ring takes place. After cooling, the ring is placed on a special brass gauge, a pointer on which measures the contraction over a degree scale. This scale is calibrated from 1 to 50, the corresponding temperatures being 960° to 1310° C. (B. 106.)

Bull's Eye. Temper carbon surrounded

by ferrite. A formation sometimes seen in *blackheart malleable iron.*

Bumper. A jolting machine used in the foundry for ramming the sand in the mould.

Bunch. A mining term for a pocket of ore.

Bundle. Two or more coils of wire or any number of lengths of wire bound together.

Bundyweld Process. A method of tube production in which copper coated steel strip is first rolled twice around laterally into tubular forms. Its overlapping plies and seams are then brazed in a furnace, the copper coating acting as the brazing agent. It is then cooled slowly in a special cooling furnace. The finished product is solid, double walled, scale free, tubing brazed through 360° of wall contact. It is built to withstand high pressures and vibrations.

Bung. A section of the roof of an *air furnace.*

Bunsen Burner. A type of burner in which the amount of air to be mixed with the gas can be adjusted mechanically before burning. It is used as a source of heat in certain laboratories.

Burden. The ratio of the total weight of the *ore* and *flux* to the fuel charged into a *blast furnace.* A heavy burden is one with a high ratio of ore to coke.

Burdening the Furnace. The determination of the ratio between *ore, flux* and fuel best suited to the *blast furnace* conditions.

Burdett Burn Off Process. A process of rust proofing which consists primarily of the proper placing of gas-fired infrared burners in relation to the work. It is claimed that the process not only removes grease and similar film, but simultaneously produces a blue rust-resistant surface on the metal. (I. 8.)

Bureau of Standards Wear Test. A method for accurately measuring the wear that takes place on the bearing surfaces of machinery. It consists of making minute indentations in the wearing surface by means of a specially shaped diamond point and measuring the dimensions of marks before and after wear. (M. 10.)

Burette. A cylindrical graduated glass tube fitted with a ground glass stop cock, used for the measurement and delivery of small volumes of liquid, as for example in titrations in volumetric analysis.

Burlington Process. A method for the production of long cast cylinders and tubes.

Burning. (See BURNT STEEL.)

Burning In. (*a*) A roughening of the surface of a casting due to metal having penetrated into the sand. (*b*) (See FLOW WELDING).

Burning Off. In *spectrographic analysis,* burning off applies to the process of purifying or pretreating electrodes by causing a discharge to take place between them, this discharge period not being continuous with exposure time.

Burning On. (*a*) The adherence of sand to the surface of steel castings. (*b*) (See CASTING ON). (B. 32.)

Burn Through. (See BURNING THROUGH THE PLATE.)

Burning Through the Plate. (BURN THROUGH). This term as used in welding, refers to the burning away of the metal at the joint due to improper welding procedure, e.g. excessive heat or too slow, or erratic welding speed. (T. 13a).

Burnishing. An operation in which the work is given a high finish or lustrous surface either by the application of highly polished tools, of agate or steel, or by being rolled in a barrel with hardened steel balls (or some modification thereof) or in some cases, without the steel balls, where the load consists of such parts that they can be self-burnishing. In either case, however, no abrasive is used. Instead, a lubricant is added for the express purpose of avoiding metal to metal contact, regardless of whether steel balls are used or not. Metal is not removed from the work, and dimensional changes do not occur. (M. 143.)

Burns and Riegels Test. (*S.A.C. Hardenability Test.*) An extension of the *Penetration Fracture Test* in order to include steels down to 0·1% carbon, in which the test pieces are quenched under standard conditions and fractured. A hardness traverse is carried out and the steel is characterized by the following rating:

S = Surface Hardness
A = Average Hardness
C = Centre Hardness (H. 71.)

Burnt Edges. Edges which have become broken during hot rolling due to overheating or burning.

Burnt on Sand. A misnomer usually indicating metal penetration into sand resulting in a mixture of sand and metal adhering to the surface of the casting. (A. 26.)

Burnt Ore. (See BLUE BILLY.)

Burnt Sand. Sand in which the *binder* has been burned by contact with molten metal. (A. 26.)

Burnt Steel. The term is usually applied to a condition in which visible oxide films are formed at the crystal boundaries of the steel. This denotes that the steel has been heated almost to the *solidus* temperature, and is therefore

permanently damaged. Sometimes there are no films present but the fracture shows faults. (W. 70.)

Burr. (*Flash* or *Fash.*) A rough or sharp edge left on metal by a cutting tool.

Burrel Combustron. An electronic instrument for rapid and accurate determination of carbon by combustion.

Burst. An internal discontinuity caused by incorrect *heat treatment* or forging.

Burst Edges. Defects in sheet or strip due to excessive cold rolling which results in the bursting of the edges of the work.

Bursting Expansion. A description applied to the swelling which occurs when chrome or chrome-magnesite refractories absorb iron oxide. Magnetic oxide of iron (Fe_3O_4) is the only iron oxide which will cause bursting expansion, being isomorphous with the chrome *spinels* and readily forming solid solutions with them. The true nature of bursting expansion is still somewhat obscure. However, magnesia and its silicates tend to diminish the expansion, probably by retarding access of the iron oxide to the spinel grains whilst any factors tending to increase the surface area of the spinels, e g. twinning or shattering of grains, etc., also increase the bursting expansion. In steel melting furnaces, bursting expansion causes slabs of about 1½ in. thickness to fall or peel away from the mass of chrome-magnesite brickwork. The absorption of oxide then recommences and bursting expansion causes further peeling.

Burton Portable Hardness Tester. This tester, which incorporates a diamond indenter, weighs only 3 lb., and gives direct readings in Vickers pyramid, Brinell, and Rockwell C values. In use, the base of the instrument is pressed on to the workpiece by a pivoted handpiece, the reading then being observed on the dial-type indicator.

Busch Metaphot Photo-Visual Microscope. An instrument by which either visual microscopic or photomicroscopic examinations can be made, using various methods of illumination. A mirror mounted in the base reflects the image on to a conveniently placed focusing screen. A heavy cast-iron base also forms the housing for the camera which has a fixed extension of 50 cm., and the focusing screen gives twice the magnification obtainable with the same optical system when used for visual examination. (M. 26.)

Busch-Schumann Projector. An apparatus for reading Brinell ball impressions which is claimed to relieve eye-strain. (Z. 9).

Bushelling. The process of heating to a welding heat in a *reverberatory furnace*, miscellaneous iron, and or steel scrap cut into small pieces.

Business Names. Under the Registration of Business Names Act 1916, a business carried out under any name other than the name of the owner must be registered. Likewise, a limited company which trades under a name other than its corporate name must register. Application should be made to the Registrar of Business Names, Bush House (S.W. Wing), Strand, London, W.C.2, or Exchequer Chambers, Parliament Square, Edinburgh. The fee is five shillings.

Bustle Pipe. The large pipe encircling the *bosh* of a *blast furnace*. It receives the hot air from the *stoves* and distributes it to the *tuyeres*.

Bustling. A bundle of light iron scrap.

Busy Metal. A metal which is subjected to repeated cold rolling, vibration, or abrasion in service. It corrodes more slowly and more uniformly than metal not in use. Thus, rails on the main line of a railroad usually show much less corrosion than those on the sidings. The effect in this case is probably due to the shaking off of the hygroscopic rust which collects moisture from the air. (S. 88.)

Butler Finish. (See SATIN FINISH.)

Butt Joint. A joint where the ends or edges of the parts are directly opposite each other.

Butt Seam Welding. A seam welding process with the pieces positioned edge to edge.

Butt Weld. A weld made by the resistance butt-welding process where two parts of similar cross section are joined together end to end, the joining weld lying between them.

Butt Welding Process for the Production of Tubes. (*Jump Welding.*) Hot rolled strip, having square or slightly bevelled edges (*skelp*) and of a width to give the desired circumference of the finished tube, is heated to welding temperature and drawn through a suitably shaped die, known as a *welding bell.* The strip is thus formed into a cylindrical shape, and its edges are finally pressed together and joined into a *butt* or *jump weld.*

Buttering. A method of facilitating metal arc welding in which the parts to be welded are given a preliminary covering of the weld metal prior to the actual welding operation.

Button. (See FERRO-TUNGSTEN.)

Button Test. A test frequently used in the examination of galvanized wire. About a foot of wire is bent back and

coiled round itself, lack of adhesion and any brittleness in the coatings being shown up by the various degrees of cracking and flaking produced in the coil. (P. 51.)

Byers Process. (*Aston-Byers Process.*) Process for making *wrought iron*, in which the *pig iron* is melted in a *cupola*, desulphurized in a *ladle*, and then subjected to refinement in a *Bessemer converter*. After tapping into a *ladle*, the refined iron is poured at a regulated rate into another ladle containing molten *slag*, held considerably below the melting temperature, which causes freezing of the iron. The excess slag is poured away, and the metal sponge ball separately delivered to a squeezing press. (R. 5.)

B.W.G. Birmingham Wire Gauge.

B.W.R.A. British Welding Research Association.

C

C. (*a*) Chemical symbol for *carbon*. (*b*) Abbreviation for *Thermal Conductance*.

°C. Degrees *centigrade* or *Celsius*.

Ca. Chemical symbol for *calcium*.

C.A. *Close annealed*.

C.A.B. (See CRITICAL AIR BLAST.)

C. and F. Cost and freight.

"C" Process. (See CRONING.)

Cabbling. A term used in the U.S.A. for cutting up *puddled bar* preparatory to *faggotting*, in the production of wrought iron.

Cable Iron. Wrought iron for the production of cable.

Cadalyte Process. A proprietary name for a cadmium coating process. The plating bath contains cadmium oxide dissolved in sodium cyanide together with certain brightening agents, whilst the anodes consist of a cadmium alloy containing small percentages of mercury and zinc.

Cadmia. (*Philosopher's Stone.*) Oxide of zinc sometimes deposited in the upper part of a blast furnace when the iron ore has contained traces of zinc.

Cadmium. (*Cd.*) *Atomic weight* 112·41. *Specific gravity* at 20° C., 8·648. *Melting point* 321° C. A white metallic element. It is used for coating small steel articles as a protection against corrosion. Cases of poisoning have arisen which are alleged to have been caused by the effect of mildly acidic foodstuffs on cadium plating. Therefore, it should not be used where it is likely to come into contact with food or drink.

Cadweld. A method for welding copper to copper or copper to steel in which no outside source of heat is required. It is similar to *thermit welding* with the exception that iron oxide has been replaced by copper oxide. Reduction of copper oxide by the aluminium used in the process yields molten copper at about 2185° C. and aluminium oxide slag. (R. 9.)

Caesium. (*Cs.*) *Atomic weight* 132·91. *Specific gravity* 1·9. *Melting point* 28° C. A metallic element in the first group of the periodic system; one of the alkali metals. It is silvery-white in colour and is so soft that it can be cut with a knife. Caesium reacts explosively with oxygen or water and is the most strongly basic and electropositive metal known. Its chief use is in photo-electric cells as variation in the intensity of light or X-rays falling upon it results in the corresponding emission of electrons.

Cake. A coalesced mass of unpressed *metal powder*. (G. 30.)

Calcar. An archaic name for an annealing furnace.

Calcareous Ores. Iron ores in which the *gangue* consists mainly of carbonate of lime.

Calcination. The concentration of iron ores by roasting or burning to drive off carbon dioxide, etc., and to oxidize the iron to the ferric state.

Calcination Furnace. (*Calciner.*) A furnace or kiln used in the calcination of ore. In this country, iron ores are usually calcined in kilns of which there are many forms.

Calciner. (See CALCINATION FURNACE.)

Calciovolborthite. ($(Cu,Ca)_3V_2O_8.(Cu,Ca)(OH)_2$). A vanadium ore.

Calcite. (*Iceland spar.*) (*Calcspar.*) A mineral consisting of calcium carbonate ($CaCO_3$). Sometimes used as a flux in place of limestone.

Calcium. (*Ca.*) *Atomic weight* 40·08. *Specific gravity* at 20° C. 1·55. *Melting point* 850° C A silvery-white metallic element. It may be added to steel as a deoxidizer and degasifier. One method of adding the calcium is to shoot it into the ladle of molten metal with a compressed-air gun, and by this method a 60-ton ladle of steel can be deoxidized in about 5 minutes using about 2 lb. of calcium per ton of steel. In the manufacture of chromium-nickel steels it is claimed to give clean grain boundaries, uniform grain size and to retard the formation of carbides. The addition of calcium to a hypereutectic iron yields a grey cast iron in which the free carbon is present partly or wholly in the form of nodular graphite, with consequent enhancement of the mechanical properties. It is claimed

Campaign. The period during which a furnace is in continuous operation.

Campanil. An iron ore mined in Spain. It is dark red to purple in colour and contains about 50% of metallic iron, the *gangue* consisting chiefly of calcium carbonate.

Campbell, Professor Edward Demille. (1863–1925.) An American metallurgist whose work was directed to the correlation of the chemical and physical properties of steel.

Campbell Process. A modification of the *basic open hearth process* in which a charge of pig iron and scrap is melted in a *Campbell tilting furnace* and held at a low temperature. During this period the phosphorus and silicon are largely eliminated, together with some of the manganese and sulphur, without reducing the carbon content to any considerable extent. The steel is then tapped into a ladle, separated from the slag, and then charged into an *acid open hearth*, where the heat is finished under a normal acid slag.

Campbell Tilting Furnace. A modification of the normal stationary *open hearth furnace* in which the hearth is constructed so that the axis of tilting is coincident with the centre of the *ports*. The furnace may be tilted without shutting off the gas or air, the *tap hole* being replaced by a pouring spout.

Canaris Method. A process by which steel, to which no silicon has been added, is rendered sound by plunging a canister containing *thermit* right to the bottom of the mould immediately after teeming. An iron rod is used to thrust the canister down. For ingots from 3 5 to 8 tons, the weight of the thermit addition is 2 5 kilograms. (G. 32.)

Canfield's Reagent. An etchant containing 1·5 g. cupric chloride, 5 g. nickel nitrate, 6 g. ferric chloride, in 12 ml. of hot water. It is used for revealing phosphorus segregation in iron and steel.

Can. G.P. Canadian Government Purchasing Standards Committee.

Cansa. (*Chapinha.*) Hydrated Brazilian haematite ore resulting from the weathering of *itabirite*.

Cantilever Bending Creep Test. The essential feature of this test is that a small specimen is held in a block of heat-resisting steel by a slack push fit into a hole in the block which is enclosed by a tube furnace. The specimen is loaded by a beam secured to the specimen in a similar way. Two side arms extending from the block carry a reference point against which the deflection of the beam is measured on a scale attached to the end of the beam. (H. 20.)

CaO. Chemical formula for calcium oxide, *lime*.

Capacitative Heating. The heating of non-conductive materials by means of the dielectric losses occurring therein when they are placed in an electric alternating field. (S. 134.)

Capillary Action. The force or action which operates when a tube of glass, the bore of which is very small in diameter and which is open at both ends, is placed vertically with its lower end immersed in water, causing the water to rise in the tube and reach a higher level on the inside of the tube than on the outside.

Capillary Attraction. The phenomenon by which adhesion between the molten filler metal and the base metals, together with surface tension of the molten filler metal, distribute the filler metal between the properly fitted surfaces of the joint to be brazed, or soldered.

Capillary Pipe. A fine pipe extending along the junction of a weld and parent metal. It is caused by defects in the parent metal such as lamination or segregation.

Capillary Tubing. Tubing with a very fine bore.

Capped Steel. Steel possessing *rimming* properties, which has been subjected to *capping*. Such steel is characterized by blowholes, often only ¼ in. or less, below the ingot surface, in contrast to the deeper-seated blowholes of *rimming steel*, cast in open-top moulds. (V. 5.)

Capping. (*Plugging.*) The process of sealing the top of an ingot mould immediately after casting a *rimming steel*, by means of sand or more frequently by means of a plate or cap-shaped closure of cast iron or steel. Such covers may weigh up to about 2 cwts. (See also CAPPED STEEL.)

Caquot Fatigue Testing Machine. A fatigue machine of the rotary type for the simultaneous testing of a large number of small test pieces, the latter being of a special shape. (P. 47.)

Carapella's Reagent. An etchant consisting of 5 g. ferric chloride dissolved in 96 ml. ethyl alcohol to which has been added 2 ml. of hydrochloric acid. It is used in etching non-ferrous metals and manganese steels.

Carat. (*Karat.*) (*a*) A standard of weight for precious stones. The metric carat, standardized in 1932, equals 200 mg. (⅕ of a gram). (*b*) The standard of fineness of gold. (See GOLD.)

Carbanalyzer. (*Carbometer.*) An instrument for the determination of carbon in steel, used in the control of the *open hearth process*. The operation depends on the principle that the magnetic

characteristics of a steel vary with composition, the meter reading being a function of permeability. (W. 14.)

Carbide. A chemical combination of carbon with iron or any other element, e.g. Fe_3C (*cementite*). Metallic carbides are hard and brittle; certain of them, of which the principal are tungsten carbide (WC) and titanium carbide (TiC), are the chief constituents of the cemented carbides used for cutting tools. In commercial usage, the term carbide generally refers to calcium carbide. (See HARD METALS.)

Carbide Etching. The selective etching of iron or steel with the object of revealing any carbides present. Various reagents may be used, e.g. *Pilling's Reagent* and *Murakami's Reagent*.

Carbide Former. An element which reacts chemically with the carbon present in the steel to form a carbide, e.g. titanium, niobium, tantalum, chromium and tungsten.

Carbidizing Treatment. A method of case hardening stainless steels which involves the simultaneous adsorption of carbon and metallic alloying elements. In theory, this should overcome the objection to normal methods of case hardening stainless steel by nitriding or carburizing, i.e. that chromium combines with the nitrogen or carbon and is not, therefore, available for conferring corrosion-resisting properties.

Carbodrip Process. A method of *drip feed gas carburizing* in which a suitable organic liquid such as a mixture of alcohol and hydrocarbons is dripped directly into the carburizing furnace with the object of producing a reaction gas directly *in situ*. (M. 128a.)

Carboflux Arc Welding. A method of *carbon arc welding* using flux-coated filler rods and a flux-coating on the sheets to be welded. It is suitable for the butt welding of austenitic 18/8 type steels from about 14 to 22 S.W.G. Direct current is essential, and the carbon electrode is connected to the negative pole. The flux, which is supplied in powder form, is mixed with water to the consistency of thick cream, and is painted on the top and underside of the sheets to be welded. (M. 20.)

Carbofrax. A neutral refractory material consisting of *carborundum* bonded with clay.

Carbometer. (See CARBANALYZER.)

Carbo-Nitriding. (*Nicarb Process.*) A method of producing a hard case on steel by introducing both carbon and nitrogen into its surface at a temperature between 800° and 875° C. The steel is then cooled at a rate required to give the desired properties. Electric furnaces must be specially designed for this process and may be of the batch or continuous types. The atmosphere, which is both carburizing and nitriding, is obtained by the addition of ammonia and hydrocarbon to a carrier gas produced from town gas. The ratio ammonia : hydrocarbon : carrier gas is varied according to the temperature of treatment and the nature of the case required. The hardened case produced by carbo-nitriding is similar in many respects to that obtained by liquid cyaniding. It is claimed that in comparison with gas carburizing, the case has a greater resistance to wear and that less distortion occurs because lower treatment temperatures are used. (G. 9.)

Carbon. (*C.*) *Atomic weight* 12·01. *Melting point* above 3500° C. A non-metallic element. It occurs in several *allotropic* forms, e.g. in the *crystalline* form as graphite and diamond, and in the amorphous form as charcoal and coke. It is one of the transition elements, with many of the characteristics of both metals and non-metals. Carbon is inert to chemical action and has good high temperature strength and excellent resistance to thermal shock, high sublimating or boiling points, good heat conductivity, high heat of vaporization, and good arc characteristics and electrical conductivity. It is used in the form of graphite for electrodes, and has been tried as a blast furnace refractory, particularly in the region of the hearth, but evidence regarding its suitability for such applications appears to be very contradictory. The presence of carbon is essential in steels which have to be hardened by quenching, and, for example, in austenitic manganese steel which is required to have high resistance to wear. The maximum hardness obtainable in any carbon steel is a direct function of the carbon content which may vary up to about 2% according to the purpose for which the steel is to be used. It occurs in varying forms according to the percentage present, and the heat treatment to which the steel has been submitted. (See IRON-IRON CARBIDE DIAGRAM, ALLOTROPY and TRANSFORMATION RANGE.) Cast irons usually contain from about 1·8% to 4·5% carbon, present either as free carbon (*graphite*) and/or combined carbon (*cementite*), the varying distribution of the carbon between these two forms considerably influencing the strength and hardness. (See Plates VII and VIII.) (See also CARBON STEEL.)

Carbon Arc. The arc formed by an electric current passing from one carbon electrode to another or from one carbon

electrode to another electrical conductor. The intense heat thus produced is used in many metallurgical operations, e.g. *Carbon Arc Cutting, Carbon Arc Welding* and in the *Electric Arc Furnace.*

Carbon Arc Cutting. Cutting metal by means of the *carbon arc.*

Carbon Arc Welding. A process in which fusion is attained by maintaining an electric arc between the work and a short stiff carbon electrode that is readily controlled by the operator. This electrode allows the process to be used on welds which may be very difficult of access by any other process. A filler wire is used, and is fed into the molten pool in the same way as in the oxy-acetylene process. Direct current from a motor-generator set is always used, with the electrode negative. The filler wire is flux coated, and suitable fluxes for coating the joints are marketed. Butt, fillet, and edge welding, have all been successfully applied at various times. No *shielding* is used. (L. 6.)

Carbon Bar Furnace. (See GRAPHITE BAR ELECTRIC FURNACE.)

Carbon Case Hardening. The term is usually applied to the complete process of *carburizing* or *cyaniding* low carbon steels, with or without one or more further heatings to promote grain refinement, followed by quenching, in order to produce a hard case. The high carbon content of the exterior of the steel so treated renders the surface hard and wear-resistant, while the low carbon content of the interior, which remains virtually unaffected, leaves the core tough and ductile

Carbon Dioxide. (CO_2.) A colourless gas produced when carbon is burnt in air, when limestone and magnesite are burnt, and by the action of hydrochloric acid on calcium carbonate. It is a stable compound and can be liquefied at 0° C. under a pressure of 34 atmospheres and is used in this form as *carbon dioxide snow.*

Carbon Dioxide Snow. (See CARBON DIOXIDE.)

Carbon Electrode. (*a*) A non-filler metal electrode, consisting of a carbon or graphite rod, as used in *carbon arc welding.* (*b*) An electrode in an electric arc melting furnace.

Carbon Electrode Arc Welding. A group of *arc welding* processes wherein carbon electrodes are used. These include *shielded carbon arc welding, inert gas carbon arc welding, carbon arc welding* and *twin carbon arc welding.* (A. 37.)

Carbon Equivalent. (*a*) A relationship of the total carbon, silicon and phosphorus content in *grey iron* expressed by the formula $\text{C.E.} = \dfrac{\text{T.C\%} + \text{Si\%} + \text{P\%}}{3}$

(*b*) In welding, a formula designed to indicate the relative importance of the various elements in connection with the tendency to the cracking of weldments due to the formation of hard zones. The Dearden and O'Neil formula is:

Carbon Equivalent =

$$C + \frac{Mn}{6} + \frac{Cr}{5} + \frac{Ni}{15} + \frac{Mo}{4} + \frac{Cu}{13}$$

According to J. G. Ball (B. 10a) if the carbon equivalent is greater than 0·48–0.06t (where t is the thickness in inches) preheating to at least 200° C. should be carried out prior to welding to obviate cracking.

Carbon Free. A quality of metals and alloys containing an unusually low carbon content which renders them suitable for particular applications, e.g. carbon free ferro chromium contains a maximum of 0·03% carbon and is, therefore, particularly suitable for the production of certain qualities of austenitic corrosion-resistant steels.

Carbon Gradient. The drop in carbon content from the surface of a *case-hardened steel* to unaltered *core* or vice versa in a decarburized steel. In case-hardened steels a steep gradient is to be avoided as it involves the risk of portions of the surface flaking off during quenching.

Carbon Monoxide. (*CO.*) A poisonous gaseous product of incomplete combustion formed when carbon is heated in a limited supply of air, when *carbon dioxide* is heated with carbon or when carbon dioxide is passed over certain metals at elevated temperatures. It is used as a reducing agent.

Carbon Restoration. The process of recarburizing steel whose surface has become decarburized during prior treatment.

Carbon Steel. A steel whose properties are determined primarily by the percentage of carbon present. Besides iron and carbon, such steels may contain a maximum of manganese up to 1·5%, silicon up to 0·5%, sulphur and phosphorus up to 0·1%, nickel up to 0·40%, chromium up to 0·30%, molybdenum up to 0·15%, copper up to 0·25%, tungsten, cobalt, aluminium up to 0·10%, and niobium, tantalum, titanium, vanadium, zirconium up to 0·05%. These alloying elements in such quantities are regarded as residual elements, but their deliberate addition in substantial amounts will relegate the steel to the *alloy steel* category. (See Plates

VII and VIII.) (See also CARBON and IRON-IRON CARBIDE DIAGRAM.)

Carbonado. A black variety of diamond which is highly resistant to fracture and hence is used in industrial cutting, as, for example, in rock drills.

Carbonal Process. A method of carburizing which consists primarily of heating the work thoroughly in a retort and then admitting oil, which is caused to impinge on the hot walls of the retort by a rapidly revolving fan. The oil is thus transformed into an active carburizing gas. The means provided for accurate control of the heat and the amount of oil admitted make it possible to obtain uniform results. (T. 52.)

Carbonia Finish. (*Gun Metal Finish.*) An oxide finish for rifle barrels, etc., obtained by placing the steel articles loosely in a retort together with a small amount of charred bone and heating to about 400° C. When the steel is completely oxidized, the temperature is lowered to about 350° C. and a mixture of bone and carbonia oil is added and heating is continued for some hours. The articles are removed and immersed or tumbled in oil to produce a uniform black finish.

Carbonization or Carbonizing. The process of coking or driving off the volatile matter from coal, wood, etc. Carbonization should not be confused with *carburizing*.

Carbonyl. A compound of carbon monoxide and a metal, e.g. nickel carbonyl, obtained as a low-boiling-point liquid by the interaction of carbon monoxide and nickel under atmospheric pressure at temperatures between 30° and 50° C. The carbonyl is readily dissociated by heating above its boiling point and, depending on the condition of decomposition, metallic nickel can be obtained as a very fine powder or as shot, built up from deposited metal. The metal powder so obtained is very pure and is widely used in powder metallurgy. Iron carbonyl is formed in a similar manner from iron and carbon monoxide and is readily converted to iron powder. (M. 142.)

Carbonyl Powder. Particles produced by the thermal decomposition of a *metal carbonyl*.

Carborundum. An abrasive consisting essentially of *silicon carbide* (SiC) which is manufactured by sintering a mixture of coke, sawdust, sand and salt between the electrodes of a special furnace. The carborundum so produced is suitably graded and bonded with clay or with one of a number of other materials, and used in the form of grinding wheels and sharpening tools.

Carbozite. A black liquid, made from a bituminous ore, used for the protection of steel surfaces during transport and storage. This fluid dries rapidly to a hard gloss, which is resistant to acids, alkalis, moisture, sea air and temperatures up to about 200° C. (S. 118.)

Carburizing. The introduction of carbon into the surface layer of a steel having a low carbon content (*case-hardening steel*). It may be effected by heating in a solid, liquid or gaseous carbon-containing medium, which at high temperatures provides a supply of nascent carbon for absorption by the material being carburized. By controlling the temperature and time of treatment, the concentration of carbon in the surface of the steel and the depth of penetration may be varied over wide limits. Up to the present time, the process mainly used in this country has been that of *box-* or *pack-carburizing* in which the steel is heated to the necessary temperature in a solid carburizing compound, usually a mixture of hardwood charcoal and an oxide or carbonate of the alkalies of alkaline earths. *Gas carburizing* is finding increasing use in this country. (See also CARBON CASE HARDENING, LIQUID CARBURIZING and SELECTIVE CARBURIZING.) (J. 11.)

Carburizing Flame. (See REDUCING FLAME.)

Card of Patterns. A number of patterns fastened together. (A. 26.)

Carnotite. ($K_2O.2UO_3.V_2O_5.3H_2O$). A mineral forming an important source of radium, uranium, and vanadium. It is a vanadate of uranium and potassium.

Caron's Cement. (*Hardenite.*) A case-hardening compound consisting of a mixture of 3 parts of powdered charcoal, with 2 parts of barium carbonate.

Carpenter, Henry Cort Harold, F.R.S. (1875–1940.) Professor of Metallurgy at the Royal School of Mines. He initiated researches on the equilibrium diagrams of binary and ternary alloy systems, the growth of cast iron and the growth of metallic crystals after mechanical strain. This led to the study of the properties of single crystals and their modes of deformation.

Carpenter Tapered Test Bar. A tapered cone test specimen for measuring the hardenability of shallow hardening steels. The parameter used to designate the hardenability is the cooling rate in degrees Fahrenheit per second at 1300° F. (705° C.) at which the steel must be cooled to attain the critical hardness or a 50% *martensite*—50% *troostite* structure. (P. 38.)

Carry Over. (*a*) The entrainment of liquid or solid particles in the vapour

from a boiling liquid. (*b*) The liquid or particles so entrained.

Carrying Plates. Iron plates used to support certain portions of *sand-* or *loam-moulds.* (P. 1.)

Carter Process. A method of laying out designs. Full-scale drawings made on specially prepared translucent paper are placed on the metal sheets to be fabricated, these having been previously sensitized in photographic emulsion. Thus, the full-scale drawing becomes the photographic negative, and after exposure, development and fixing, the sheet to be fabricated bears the image of the drawing. (C. 14.)

Cascade. (See GASSIOT'S CASCADE.)

Cascade Method for Pouring Ingots. The steel is poured from the ladle through a trough or box into moulds stepped one below another, the moulds being so connected that the metal overflows from the highest mould into the next, and so on, until the last mould is filled. It is claimed that steel poured in this manner shows less piping and segregation. (M. 165.)

Cascade Sequence. A combined longitudinal and build up sequence in which weld *beads* are deposited in overlapping layers. (See also BLOCK SEQUENCE, BUILD UP SEQUENCE, and LONGITUDINAL SEQUENCE.) (A. 37.)

Case. (*a*) The surface layer of an iron base alloy which has been suitably altered in composition and can be made substantially harder than the interior or *core* by a process of case hardening (*b*) (See COPE).

Case Hardening. (See CARBON CASE HARDENING.)

Case-Hardening Mixture. Material of which the essential constituent is carbon, which may be present in the form of wood or animal charcoal. The action of the charcoal is greatly improved and accelerated by the admixture of 30% to 40% of barium carbonate or 5% to 10% of soda ash, which acts as an *activator* or *energizer.*

Case-Hardening Steel. (See CARBURIZING.)

Cased Tube. A *close joint* steel tube over which has been drawn another tube, which may be close joint, seamless or welded, but which consists of another metal.

Caspersson's Method. A method of teeming in which the molten steel is poured into a tundish provided with a number of small holes, through which the metal passes in fine streams. The object of the process is to allow the contained gases to escape.

Cassel Process. (See SULFINUZ PROCESS.)

Cassette. A case used in X-ray photography for holding a film during exposure.

Cassiopeium. A name suggested, but discarded, for *lutecium.*

Cassiterite. (See TIN.)

Cast. (*a*) (*Heat*). The product of a single charge of an electric or open hearth furnace or a *blow* of a *Bessemer* furnace. (*b*) The shape adopted by a length of wire when free from constraint. (*c*) When used as an adjective see CAST STEEL. (*d*) When used as a verb see CASTING.

Cast Coating. (See COMPOSITE CASTING.)

Cast Gate. The *ingate* at which the metal is poured into the *mould.*

Cast House. A small roof-covered platform traversed by cast iron runners which carry the iron and slag tapped from the *blast furnace* into large refractory-lined containers mounted on railway trucks. (S. 152.)

Cast Iron. Iron with a total carbon content varying between about 1·8% and 4·5%, the carbon being present in excess of the amount which can be retained in solid solution in *austenite* at the eutectic temperature. In addition to carbon, there are also present, varying amounts of silicon, manganese, sulphur and phosphorus. These irons can normally be divided into the following types: *Grey cast iron,* in which all or part of the carbon content is in the form of graphite distributed through the metal as flakes or lamellae, the latter being responsible for the inherently poor shock-resistance and relatively low mechanical properties of the material (see Plate X(b)); *White cast iron,* in which practically the whole of the carbon is retained in chemical combination with the iron as carbide of iron, Fe_3C. This compound has a silver-white colour and the fractures of the cast iron are white. White iron is very hard and brittle and practically unmachinable, and is used chiefly as an intermediate product in the production of malleable iron castings or a thin hard layer on the surface of a softer iron casting (see Plate X(a)); *Malleable cast iron,* is cast white and then annealed at about 850° C. to remove carbon (*White-Heart Process*) or to convert the *cementite* to rosettes of graphite (*Black-Heart Process*). It is distinguished from grey and white cast iron by exhibiting some *elongation* and *reduction in area* in a tensile test (see Plate X(d)); *Spheroidal graphite cast iron,* in which the graphite is in spheroidal form instead of the flakes found in grey cast iron. Originally, the production of these irons involved the addition of an appropriate amount of cerium to the molten iron shortly before

casting, but more recently cerium has been either completely or partially replaced by magnesium, the magnesium process having the advantage of cheapness, although the use of both elements together is said to be more reliable. It is claimed that the mechanical strength is doubled and such castings show measurable ductility and greatly increased shock resistance (see Plate X (c)). *Alloy cast iron* contains a specially added element or elements in amounts sufficient to produce a measurable modification of the physical properties of the section under consideration.

Cast Iron Thermit. (See THERMIT.)

Cast Steel. (*a*) A term, originally applied to *crucible steel* to distinguish it from *shear steel*, and still used for high-carbon tool steel; (*b*) the term also covers steel which has solidified from the molten condition in a mould and hence undergoes no further change of shape, except for such minor modifications as may be involved in *machining*, *sand blasting* or any such finishing processes.

Cast Structure. The structure of a cast alloy. On a macroscopic scale it presents a cored dendritic structure, and in some alloys there is a network of other constituents.

Cast-Weld Structure. Castings produced in two or more parts and joined by welding. It is claimed that this results in lower pattern costs through the elimination of *core boxes*, and lower core room costs through the elimination of *cores*. (F. 12.)

Castability. The suitability of a steel for casting.

Casting. (*a*) A metallic shape obtained by pouring molten metal into a *mould* and allowing it to solidify, as distinct from one shaped by working. (*b*) The operation of pouring molten metals into sand or metal moulds in which they are allowed to solidify. (See also SAND CASTING.)

Casting Box. The *flask* containing the *mould*.

Casting Cracks. (See SHRINKAGE CRACKS.)

Casting Ladle. (See LADLE.)

Casting Machine. (See PIG CASTING MACHINE.)

Casting On. (*Burning On.*) A method occasionally employed for rectifying defective castings. A mould, provided with a *runner* and *riser*, is formed round the defective part of the casting and hot metal is poured in until the face of the defect is heated to welding temperature, whereupon the newly formed part becomes fused to the defective face.

Casting-On Diffusion Process. A composite casting process, in which the coating metal is cast-on to the steel backing arranged in a sand mould. After cooling, the composite casting is removed from the mould, placed in an annealing vessel, packed round with refractory material and then subjected to a diffusion heat treatment. The heat treatment temperature should lie between the *solidus* and *liquidus* temperature of the non-ferrous alloy used. (S. 31.)

Casting Shrinkage. *Shrinkage* of metal on solidification from the melt.

Casting Strains. Strains resulting from the cooling of a casting, accompanied by residual stresses. (A. 27.)

Casting Wheel. An appliance for the casting of *pig iron* in which the moulds are placed on the circumference of a wheel which is rotated so as to bring each mould in turn under the holding ladle.

Catalan Process. An iron-making process used for centuries, but now obsolete. The catalan furnace consisted of a low hearth, with one inclined tuyere, the charge of ore and charcoal being added separately. The ore was reduced by the carbon monoxide produced from the combustion of the charcoal. The blast was gradually increased, and the ore, as it became reduced, was pushed down to the hot region near the tuyere. As the charcoal burnt away, more was added, but mixed with fine moistened ore. Most of this ore passed down to the tuyere unreduced, and together with other unreduced ore, formed a slag with the gangue, the temperature of the tuyere region being sufficiently high for this purpose. The reduced part of the charge became pasty in the tuyere region, and welded readily into a bloom. When the whole of the charge was worked down, the blast was stopped and the bloom was taken out and hammered. (H. 17.)

Catalysis. The acceleration or retardation of a chemical reaction by the presence of a *catalyst*.

Catalyst. A substance which accelerates a chemical reaction but which itself undergoes no permanent chemical change.

Catalytic Agent. A *catalyst*.

Catalytic Poison. A material which neutralizes the action of a catalyst.

Cataphoresis. (*Electrophoresis.*) The migration of colloidal particles under the influence of a suitable potential difference. (B. 103.)

Catched Ingot. A steel ingot showing a surface defect caused by the stream of molten metal catching the side of the mould in pouring.

Catcher. (*a*) A worker in a looping mill who, by means of a pair of tongs catches the hot steel rod as it issues from between the rolls and feeds it back through another stand of rolls for the next pass. (*b*) In a tin-plate mill, a mechanical device for lifting the tinned plates from the exit rolls and placing them on a conveyor.

Catcher Mark. A flaw on tin-plate caused by careless operation of the plate-catching devices.

Catcher Rolls. In a tin-plate mill, a pair of rolls used to remove the coated metal from the oil bath.

Catchweight Coil. A coil of wire of unspecified weight.

Catenary Furnace. A continuous gas-fired furnace for annealing stainless steel strip up to 10 in. wide. The furnace is heated by fourteen burners on each side, some positioned above the strip and others below it. The strip hangs in a shallow curve as it passes through the furnace. Complete combustion is controlled by the gas-air proportioning valves and there is no muffle. (S. 116.)

Cathode. The negative electrode in an electrolytic cell, i.e. the electrode through which a direct current leaves a liquid or gas. It is the electrode at which reduction occurs and in corrosion processes it is usually the area that is not attacked. Typical cathodic processes are cations taking up electrons and being discharged, oxygen being reduced, and the reduction of an element or group of elements from a higher to a lower valence state.

Cathode Deposit. In the electrodeposition of metals, the metal deposited on the negative electrode (*cathode*).

Cathode Drop. The voltage drop between the nearest point of the arc stream and the negative electrode in *welding*. (B. 105.)

Cathode Efficiency. The current efficiency of a cathodic process.

Cathode Layer. A molten metal or alloy floating on a fused electrolyte, or upon which the fused electrolyte floats, and which forms the cathode of an electrolytic cell.

Cathode Rays. Streams of negatively charged particles (*electrons*) emitted normally from the surface of the *cathode* during an electrical discharge in a rarefied gas. The velocity of the electrons is proportional to the square root of the potential difference through which they pass, and is equal to 595 km. per second for a potential difference of 1 volt.

Cathode Spluttering. (See VACUUM METALLING.)

Cathodic. A term applied either in a general sense to denote an element below hydrogen in the *electrochemical series* or in a relative sense, to signify a more positive *electrode potential*. (B. 103.)

Cathodic Corrosion. Corrosion resulting from a cathodic condition of a structure, usually caused by the reaction of akaline products of electrolysis with an *amphoteric* metal.

Cathodic Etcher. An instrument, by means of which the sample of metal to be studied is bombarded with a glow discharge under a vacuum or at certain low pressures. The glow discharge which etches the surface of the metal under examination is produced by positive ions passing between an aluminium anode and the sample of metal. It is claimed that the advantage of this technique (i.e. by *cathodic vacuum etching*) lies in the fact that the etching is produced physically rather than chemically, so that there is less danger of forming oxides and other chemical compounds. (A. 29.)

Cathodic Pickling. (See ELECTROLYTIC PICKLING.)

Cathodic Polarization. That portion of the polarization of a cell which occurs at the cathode.

Cathodic Protection. The use of a particular metal as *cathode* in the corrosion cell as a means of protecting that metal against *electrochemical corrosion*. This may be accomplished by the attachment of a more anodic metal or by the use of an applied potential. The principle may be applied, for example, as a means of preventing corrosion of steel tanks. In this case the equipment consists of one or more electrodes of stainless steel or graphite so fixed in the water and connected to a source of direct current supply that the whole forms a current in which the electrodes are anodes and the body of the tank is the cathode.

Cathodic Vacuum Etching Process. A process utilizing ionized atoms, for preparing metal surfaces for microscopic examination and photography. It is claimed that this process enables structural characteristics, such as *flow lines* in forgings, to be observed with unusual clarity. (See CATHODIC ETCHER.)

Catholyte. The electrolyte of an electrolytic cell adjacent to the cathode.

Cation. The positively charged ion of an electrolyte which carries the positive charge in the direction of the current and delivers it at the *cathode*.

Catopter. A reflecting optical instrument; a mirror.

Cauliflower Top. (*Spongy* or *Rising*

Top.) An irregular sponge-like formation on the head of an ingot resulting from an evolution of gas when the steel has cooled to such a degree that it is too viscous to allow the gas to escape completely.

Caulk Weld. (*Seal Weld*.) A weld used to seal a joint.

Caulking. (*a*) The process of making a joint tight to withstand leakage or pressure, by packing with yarn or tow followed by lead. (*b*) Closing the spaces between overlapping riveted plates, by hammering the edge of the upper plate into intimate contact with the lower plate.

Caulking Tool. A chisel-shaped instrument with a blunt edge, which can be used for deforming metal without cutting it.

Caustic Cracking. (*Boiler Embrittlement*.) (*Caustic Embrittlement*.) A type of intercrystalline cracking due to *stress-corrosion* effects that may be formed below the water line in boilers, usually at the riveted joints or seams where concentration of alkaline salts may occur. It is not found in seamless or welded vessels except possibly at attachments for fittings. The corrosion effect is due to the hydrolysis of sodium carbonate present in the boiler water. The term *caustic embrittlement* is a misnomer since it implies that the original ductility of the material as a whole has become impaired, which is not the case.

Caustic Dip. Immersion in a solution of sodium hydroxide to clean the surface or, when working with aluminium alloys, to reveal the *macrostructure*. (A. 27.)

Caustic Embrittlement. (See CAUSTIC CRACKING.)

Caustic Potash. (*KOH*.) Potassium hydroxide.

Caustic Silver. ($AgNO_3$.) *Silver nitrate*.

Caustic Soda. (NaOH.) Sodium hydroxide.

Cavendish, Hon. Henry. C. (1731–1810.) An English scientist who determined the nature of hydrogen, and proved the composition of water and of air by volume.

Cavendish Laboratory, University of Cambridge. Research on experimental physics, including atomic and molecular physics, radio-activity, properties of matter, optics, magnetism and radio-telegraphy.

Cavitation. (*a*) (See SHRINKAGE CAVITIES). (*b*) The formation and collapse of cavities in a stream of flowing liquid which results from pressure changes within the stream caused by changes in the velocity of flow. The formation of cavities is closely related to boiling. However, as far as the mechanics of the process are concerned, it is not necessary that the cavities be vapour-filled. (K. 33.)

Cavitation Erosion. A type of wear such as that on ships' propellers, caused by impacts due to the "implosion" of cavitation bubbles in the flowing liquid. (B. 65.)

Cavitron Process. A method of shaping hard, brittle, materials. Operations, such as drilling, boring, threading, and cutting can be done easily and quickly in comparatively complicated shapes. The tool, operating head-on into the work, vibrates at an ultrasonic frequency of about 27,000 times a second, and an abrasive compound (boron carbide) is poured on to the contact area. As the tool vibrates, the abrasive particles, generally 280 mesh, flow between the tool and the workpiece. When the tool descends on the particles it drives them into the material being machined, thereby forcing the removal of small particles of the workpiece by a kind of chipping action. These are transported from the work area by the continuous flow of the abrasive compound. The tool is made of soft steel in the shape of the form to be removed, and is soldered or brazed to the small end of a truncated metallic cone. All motion of the tool originates in this cone, which produces movement by expansions and contractions caused by *magnetostriction*. (K. 15.)

Cazzaniga Process. A *hot-dip galvanizing* process in which wire is first degreased and pickled by passing it through a tank containing sodium hydroxide solution at 10° to 25° *Bé*. On leaving the pickling bath, the wire travels for about 20 cm. through the air before passing into molten zinc. During the period when the wire reaches an annealing temperature of 650° to 700° C., oxidation is prevented by an inert layer of molten soda on the wire. Finely ground *felspar* is kept on the immersion area of the molten zinc surface to prevent oxidation. The heat conveyed by the wire is normally at least sufficient to maintain the bath temperature, and means of cooling the bath are provided to prevent the zinc becoming too hot at high rates of working. The wire is wiped in the normal way after leaving the bath and it then passes straight into a water quench. A maximum speed of 150 metres per minute can be achieved. (C. 18.)

Cb. Chemical symbol for *columbium*.

C.C. *Combined carbon*.

c.c. Continuous current, usually known as *direct current*.

cc. *Cubic centimetre*.

Cd. Chemical symbol for *cadmium*.

C.D.A. Copper Development Association.

Ce. Chemical symbol for *cerium*.

Cebelcor. The Belgian Corrosion Research Centre. (See Appendix V.)

Cecomatic Impacting. A method for the automatic mass production of die forgings. The impact machine consists of two horizontally opposed, air-driven hammers, the impact energies of which are completely absorbed by the stock which is suspended in the impact plane. Electronic devices are employed to ensure that the opposing dies always hit the stock simultaneously. Jet engine turbine blades and other such parts are being made by this method, for which is claimed better grain flow, less vibration, less flashing, longer die life, and heating and power economies, compared with drop hammer forging. (H. 72.)

CeDeCut. A technique of using carbon dioxide as a coolant in metal cutting. The carbon dioxide is applied through the shank of the tool, which is bored out to provide a reservoir of coolant under the tool tip, and completely prevents its access to the chip. Surplus coolant is allowed to reach the workpiece, but none reaches the chip. At the same time the effectiveness of the coolant is increased by refrigerating the liquid carbon dioxide below room temperature so that a higher proportion of solid carbon dioxide is formed in the spray from the jet. (M. 60a.)

Cell. (*a*) A combination of two electrodes immersed in an *electrolyte*. Such a cell may set up an *electromotive force*, and if the electrodes are connected externally, an electric current will flow. (*b*) A unit for the *electrodeposition* of metals from an electrolyte. (A. 27.)

Cellular Structure. The arrangement of the constituent of a metallic, intermetallic or compound structure as a surrounding network.

Cellulosic Welding Electrode. An electrode containing 30%, or more cellulose in the coating. The balance consists essentially of titanium dioxide and magnesium or aluminium silicates together with metal deoxidizers such as ferro-manganese and liquid sodium silicates. (A. 37.)

Celsius. (1701–44.) A Swedish physicist who suggested the *Celsius scale* in 1740.

Celsius Scale. The temperature scale, in which the interval between the ice and steam points is divided into a hundred parts. It is known in this country, and in France, as the *Centigrade* scale, but the use of this word in French leads to an ambiguity, since the "grade" is the French unit of angular measure in which the right angle is divided into a hundred grades. In consequence, the use of "*Centesimale*" has been suggested in France. In Scandinavia and Central Europe, the scale is known by the name of its originator, *Celsius*. The Ninth General Conference on Weights and Measures agreed that the same name for the scale should be used in all countries, and decided in favour of Celsius. This plan has the advantage of not changing the abbreviation "°C", which is common to all languages, and it also has the effect of naming all the temperature scales in the same way, each being known by the name of its originator: *Celsius*, *Fahrenheit*, *Kelvin*, *Réaumur*. The name has been adopted by the British Standards Institution and other authorities. (I. 80.)

Cement Sand Moulding. (See RANDUPSON PROCESS.)

Cementation. (*a*) The process of introducing elements into the outer layer of metal objects by means of high temperature diffusion. (*b*) *Converting process*. In this process best quality Swedish wrought iron bars are packed in layers, separated and surrounded by charcoal, in open chests known as *converting pots*. These are then covered with *wheel swarf* which, during the subsequent heating, frits and forms an airtight seal. The chests are placed in a *converting furnace* where they are slowly heated up to a temperature of about 1100° C. and maintained at that temperature for a period of 7 to 10 days according to the desired carbon content. They are then allowed to cool slowly, the whole process occupying about 3 weeks. During this operation, carbon, provided by the charcoal, diffuses into the iron, and some of it, reacting with the slag content of the wrought iron, liberates carbon monoxide which forms blisters on the surface of the bar, hence the name *blister bar*, and *blister steel*; or *converted bar* or *cemented bar*, or *cemented steel*, or *plated bar*. If mild steel is used as the initial material, the blisters are absent, but the name converted bar is applied to either product. When a particularly high carbon content is required, the process is repeated, the product being known as *double converted bar*. Some six of these bars are then piled together, placed in a *clip*, raised to a white heat, and hammered into a *faggot* or small *bloom*. This is known as *single shear steel*. For the production of *double shear steel*, the faggot is nicked, bent back on itself, reheated and hammered down again to its original size. The process is now practically obsolete; the last cementation furnace in Sheffield

was pulled down in 1952. (*c*) A term used in the U.S.A. for a process for obtaining a metal from a solution of one of its compounds through displacement by a more electropositive element.

Cemented Bar. (See CEMENTATION.)

Cemented Carbides. (See HARD METALS.)

Cemented Steel. (See CEMENTATION.)

Cementite. The iron carbide (Fe_3C) constituent of steel and cast iron. It is hard, brittle and crystalline and contains 6·67% of carbon by weight. (See Plate VII(d).)

CEMUP. A method of *gas carburizing* which employs a mixture of propane, air and ammonia.

Census of Production. (See BOARD OF TRADE.)

Centerscope. A tool-locating device in which the operator views the work through an eyepiece, the work being illuminated during the operation by a small bulb and reflector. The object is to set the work in line with the centre line of the machine spindle to within limits as close as 0·0001 in. (E. 53.)

Centesimale. (See CELSIUS SCALE.)

Centi. A prefix meaning one-hundredth.

Centigrade. (°*C.*) A temperature scale in which the freezing point of water is taken as 0° and the boiling point, under normal atmospheric pressure, as 100°, the interval of temperature between these points being divided into 100 equal parts, each of which is a Centigrade degree. To convert a temperature on this scale to the *Fahrenheit* scale, multiply by 9/5, and add 32. (See CELSIUS SCALE.)

Centigrade Heat Unit. (*C.H.U.*) (See POUND DEGREE.)

Centigram. One hundredth of a gram.

Centimetre. One hundredth of a metre.

Central Looseness. (*Porosity.*) A defect more correctly classified as *pipe*. It is the result of a discontinuity within the metal. The porosity, however, may not be visible until the sample has been etched.

Centre Line Segregation. *Segregation* appearing at or near the axis of the ingot.

Centre of Gravity. (See CENTROID.)

Centre of Mass. (See CENTROID.)

Centre Reversal Method. A method of contour die forming in which the centre and rim of the wheel blank are kneaded alternately. (F. 21.)

Centred. (See BODY-CENTRED SPACE LATTICE.)

Centreless Grinding. Passing between abrasive rolls whose axes are parallel to that of the work.

Centri Die Castings. (See CENTRI-SPINNING.)

Centrifugal Casting. The term is applied to that method of casting in which the molten metal is poured into a *mould*, which can be either stationary or spinning, and is then allowed to solidify under a force produced by rotating the mould about a fixed axis. The molten metal is introduced into the mould along the axis. Centrifugal casting may be divided into three major types: (1) A true centrifugal casting is cylindrical and is spun about its longitudinal axis, the inner surface of the casting being formed entirely under the action of the centrifugal force. (2) A *semi-centrifugal casting* is one which is spun about its axis, but in which the central cavity of the casting is formed either wholly or partly by a core. (3) A *pressure casting* may be termed one in which the centrifugal force is used to force metal into portions which would be fed by *risers* in a static casting. The centrifugal force is merely used as a method of increasing the liquid pressure on certain parts of the casting. (D. 55.)

Centrifugal Immersion Process. A *composite casting* process using a steel bushing provided at one end with an internal flange. The bushing is mounted with its other end on to a centrifuging device, the axis of the bushing being vertical. The mounting is arranged to enable the bushing to be immersed in the molten coating alloy, while at the same time setting the bushing in rapid rotation. The molten metal heats the steel bushing, rises in the latter as a result of centrifugal action, and forms a cylindrical coating which bonds with the steel backing. (S. 31.)

Centrifugal Process of Composite Casting. In this process preheated steel backing is mounted in a centrifugal machine in which it is usually rotated with its axis in the horizontal plane, molten coating metal being poured in as the steel backing is set in rapid rotation. The steel backing can be preheated either in a molten salt bath or in a bath of the molten coating metal. In the latter case the process becomes a combination of an immersion and a centrifugal process. (S. 31.)

Centrifugal Quenching. A method of controlled quenching which may be applied to circular parts which are capable of being rotated on their central axis. The quenching media is admitted at the centre of the part and the cooling stream is directed outwards by the centrifugal force of the rotating part.

Centripetal Force. The force which causes a moving body to travel along a curve rather than a straight line.

Centrispinning. This consists essentially of the introduction of liquid metal into a rapidly rotating mould in such a way that the metal is directed under centrifugal force to take up the shape of the mould into which it is being poured. Practice can be divided into *true centrispinning* and *semi-centrispinning*, depending upon the shape and design of the component in production. In true centrispinning, the cast component rotates about a true axis in either a horizontal or a vertical position during the cycle of pouring and solidification. As the internal shape of the casting is regularly cylindrical, no cores are required, but the external shape or contour may vary according to the requirements of the application. Centrispinnings are cast in permanent metal moulds, a practice which has considerable advantages, from the point of view of both production costs and quality of product. Components produced in this way are known as *fluid forgings*, or, more generally, as *centri-die castings*. In semi-centrispinning, the internal die or contour of the component is of such irregularity that an internal refractory core is required. Generally, a refractory die is also necessary to accommodate irregularities on the outside contour of the component. As in true centrispinning, the component usually rotates about a true axis during the complete cycle of pouring and solidification, but because of complications in mould design, the axis of rotation is essentially vertical. In certain cases the shape and contour of the component are such that it is not possible to rotate it on a true axis during casting Lack of symmetry can be overcome by mounting or arranging the mould around a central axis with feeder and running gates leading to each piece from a central and common downgate. This modification is referred to as a *cluster* or *fir-tree centrifugal casting*. (T. 22.)

Centroid. (*Centre of Gravity*, *Centre of Mass*.) The point about which all the parts of a body exactly balance each other. It is the point at which the whole weight of the body may be presumed to act.

Ceramals. (*Cermets*.) (*Metamics*.) Materials produced by combining a ceramic, such as an oxide, carbide, nitride, boride, silicate or silicide, with a metal or alloy. The combination is effected at high temperatures under controlled atmospheres using methods similar to powder metallurgy techniques; the product has properties that differ from those of the components. Ceramals have good high-temperature strength together with resistance to oxidation and intergranular corrosion. Applications include gas-turbine blades, and electrical components. (See SOLARAMIC PROCESS.)

Ceramics. Products consisting of earthy materials which are either made or used at temperatures above about 550° C. In recent years the term ceramic has been extended to include products consisting of alumina and other oxides which have been produced by powder technology processes. (See CERAMALS.)

Cerium. (*Ce.*) *Atomic weight* 140.13. *Specific gravity* 6·92. *Melting point* 630° C. A metal of the *rare earth* class which in many respects resembles the alkali metals. Even at normal temperatures, it slowly decomposes water with evolution of hydrogen, and when heated in air, it burns more intensely than magnesium. Alloys containing from 55% to 85% of cerium are capable of producing copious sparks when rubbed with a file and are used extensively in pocket lighters and similar devices. Cerium is employed as an alloying constituent in certain aluminium alloys. It is stated that cerium raises the ductility and impact strength of carbon and alloy steels by changing the shape, quantity and distribution of non-metallic inclusions. A U.S.A. patent claims that the hot working properties of high alloy corrosion- and heat-resistant steels are improved by the addition of cerium, whilst in cast iron, cerium acts as a deoxidizer and desulphurizer but when the sulphur content has been reduced to a value of about 0·015%, the cerium enters into solution in the cast iron and functions as a powerful carbide stabilizer. In amounts above 0·02%, cerium has been used in the production of *spheroidal graphite cast iron*. (M. 164.)

Cermets. (See CERAMALS.)

Cerrobase. An alloy of lead and bismuth having a melting point of 124° C. It is non-shrinking on cooling, and can be used as a liquid seal for nitriding furnaces.

Cesium. (See CAESIUM.)

C.G.S. Unit. Centimetre-gram-second unit.

Chaffery. An old term for a *bloomery*.

Chafing Corrosion. (See FRETTING CORROSION.)

Chafing Fatigue. Accelerated fatigue caused by the simultaneous attack of vibration stresses and the stress raising effects of frictional contacts by lateral pressure, or chafing, such as are present in press fits, axle seats, and propeller hubs.

Chalk. A fine-grained limestone consisting of amorphous calcium carbonate ($CaCO_3$).

Chalk Test. A non-destructive test for the examination of forgings and castings in which the parts are immersed in hot paraffin and, after cleaning, covered with powdered chalk. Cracks and other defective areas then become visible.

Chalking. A defect sometimes found in coated materials. It consists of the formation of a loose powder between the base metal and the coating.

Chalybite. (See SPATHIC IRON ORE.)

Chambersberg Impactor. (See IMPACTING.)

Chambre Syndicale des Constructeurs en Ciment Arme de France Impact Test. A test for reinforcement rods. The test piece consists of a round bar, its length being ten times the diameter. In this is drilled a hole, the diameter of which is one-sixth of that of the bar, a saw-cut being made through one side of the bar to the hole. The bar is broken by a single blow, and the two pieces are fitted together again; the angle of deviation between them should be greater than 20°. (D. 13.)

Chamfer. To bevel a sharp edge. The term *full chamfer* is applied where the whole of an edge of a plate is bevelled from one or both surfaces and *partial chamfer* when a portion only of an edge of a plate is bevelled across part of its thickness from one or both surfaces, for example, when the corners are cut off the ends of the roll *barrel*, usually on plate mill rolls, they are said to be chamfered.

Chamfering. A machining operation to produce a taper on threads and gears.

Chamotte. A refractory moulding material consisting of burnt fireclay and ground firebrick melted with raw clay.

Change Points. (See TRANSFORMATION RANGE.)

Channels. Steel shapes consisting of two parallel flanges at right angles to the web. They are produced both in bar sizes (less than 3 in.) and in structural sizes (3 in. and over).

Chapinha. (See CANSA.)

Chaplet Furnace. An early type of electric arc furnace in which one of the electrodes consisted of two graphite blocks, each 12 in. × 12 in., entering by the roof in the usual way. The hearth electrode connection was not, however, disposed vertically downwards, but consisted of a channel leaving the hearth sideways, and filled with steel which partly melted during operation. It made connection in this way with a block of iron contained in a subsidiary chamber at the side of the furnace and connected with the transformer. The furnace was circular in plan and lined with magnesite, the communicating channel being lined with silica. The graphite electrodes were hand-regulated, and the furnace was tilted for pouring. This type of furnace has been used for the direct production of iron and steel from ore. The slag forming materials were first introduced into the furnace, then the mixture of ore and carbon in suitable proportions. Fusion and reduction of the charge took place in the neighbourhood of the arc, and the metal produced passed through the slag and collected on the hearth. There were two reaction zones, as in the blast furnace, an outer one in which the oxide was reduced and an inner one in which the charge was fused. Steel containing about 0·10% carbon, with low sulphur and phosphorus, has been produced by this process.

Chaplets. Metal supports wedged between the core and the mould wall to keep the core in position in the mould. Ideally, they should subsequently melt and become part of the casting, but their use is to be avoided as they sometimes fail to fuse completely with the surrounding metal.

Chapmanizing. A modification of the *nitriding* process which employs dissociated anhydrous ammonia forced into a fused cyanide bath as the nitriding agent. The stock is preheated before placing in the bath and with the ammonia thus activated, it is possible to nitride at temperatures either below or above the *critical temperature*. At temperatures above 760° C. *case* depths of 0·03 in. can be obtained in 3 to 4 hours. (G. 17.)

Characteristic X-Rays. Series of monochromatic X-rays that are emitted (in addition to heterochromatic X-radiation) by a particular element when that element is exposed to cathode rays or X-rays of sufficiently high energy. (A. 27.)

Charcoal Blacking. Charcoal used in the pulverized form as dry *blacking* or in suspension with clay as a black wash and either dusted or coated on the surface of moulds to improve the surface.

Charcoal Iron. (*a*) High-quality wrought iron, charcoal having been used as the fuel in its production. (*b*) Pig iron which has been produced in a blast furnace using charcoal as fuel and, therefore, of unusually high purity.

Charcoal Tinplate. Tinplate possessing a specified and heavier weight of coating than *coke* plates.

Charge. (*a*) The total ore, pig iron, scrap, limestone, etc., introduced into a melt-

ing furnace for the production of a single *heat* of steel. (*b*) The total quantity of electricity on an electrical conductor.

Charger. (See STEELING.)

Charging. (*a*) To pass an electric current through an accumulator thereby causing chemical changes in the elements which enable them subsequently to supply electricity to an external circuit. The quantity of electricity thus passed in providing the required amount of chemical change is usually measured in ampere-hours. (*b*) The operation of introducing the raw materials into the furnace.

Charging Door. The opening in the shaft of a *cupola* or *furnace* through which fuel, iron and limestone are introduced.

Charles' Law. (*Dalton's* or *Gay-Lussac's Law.*) At a constant pressure, the volume of a given quantity of any gas increases about 1/273 of its volume at 0° C. for each rise of 1° C., and at constant volume, the pressure of a given quantity of any gas increases about 1/273 of its pressure at 0° C. for each rise of 1° C. in temperature.

Char Mo Furnace. A furnace for the heat treating of molybdenum steels without surface decarburization. It consists of a carborundum muffle 24 in. × 12 in. × 10 in. with a refractory retort running vertically through the combustion chamber at the rear of the furnace. At the top of the retort is a hopper containing charcoal, and at the bottom a device for removing any ash. The flues and ports are so arranged that the carbon monoxide/carbon dioxide ratio can be adjusted for the particular heat treatment required, thus producing a non-oxidizing and non-decarburizing atmosphere. (I. 26.)

Charpy-Ehrensberger Pendulum Hammer. The original form (*circa* 1906) of the *Charpy impact test*.

Charpy Test. (*Simple Beam Test.*) A notched-bar impact test in which a beam, usually 10 mm. × 10 mm. in section fixed at both ends and having a notch in the middle of its length, is struck behind the notch by a striker carried on a pendulum. The energy absorbed in fracture is obtained from the height to which the pendulum rises. The notch usually has a depth of 2 mm. and is rounded at the bottom to a diameter of 2 mm. This is known as a *Mesnager* notch. A notch produced by drilling a hole usually 2 mm. diameter and centre 4 mm. below one face with a saw cut from that face to the hole, is known as a *keyhole notch*.

Charpy-Vee-Notch Test. The test consists in submitting a beam-type specimen, having an Izod notch, to a *Charpy test*.

Chatter. The continuous vibration of a cutting tool during the machining operation, due to the fact that it is not gripped efficiently or has too long an overhang. Chatter produces an uneven finish on the machined surface.

Chatter Marks. (*a*) The uneven marks on a machined surface caused by *chatter*. (*b*) The uneven surface on finished work caused by alternate gripping and slipping of the die in drawing.

CHC. (*Cyclohexylamine Carbonate.*) A vapour phase corrosion inhibitor.

Check. A crack in a *die* impression caused by forging strains. The crack usually occurs at a relatively sharp corner. (See also GRINDING CHECKS and HEAT CHECKING.)

Check Analysis. (*a*) A duplicate determination to confirm a previous result. (*b*) In the U.S.A. the term relates to an analysis of steel after it has been rolled or forged into semi-finished or finished forms. It is carried out for the purpose of verifying the average composition of a cast as represented by the *ladle analysis* or to determine variations in the composition of such a cast.

Checked Edges. (See CRACKED EDGES.)

Checker Bricks. (See REGENERATORS.)

Checking. (*a*) The development of slight breaks in the coating which do not penetrate to the underlying surface. Checking may be described as visible (as seen by the naked eye) or as microscopic (as seen under magnification of 10 diameters). (*b*) (See HEAT CHECKING).

Checquer Bricks. (*Checker Bricks.*) (See REGENERATORS.)

Cheek. The portion of a *flask* which is intermediate between the *cope* and the *drag*, when the flask is made in three parts.

Cheese. (*a*) A term usually applied to a section cut from a steel ingot which is to be subsequently punched, expanded and rolled into a tyre, but sometimes applied to sections intended for other applications. (*b*) A roughly cylindrical forging having convex sides, made by up-ending the ingot or billet between flat tools.

Cheesing. Forging into a circular form by up-ending the ingot or billet between flat tools.

Chem-Milling. A metal removal technique which consists of immersing the work in a corrosive medium until the desired amount of metal has been removed. It is claimed that surface finishes of 50 to 60 micro-in. can be attained and that the depth of attack can be controlled to within ± 0·002 in.

The action can be limited to specific areas by masking or *stopping off*, and as the masking material can be painted, printed or photographed on to the surface, the shape of the piece is unrestricted.

Chemag. A proprietary process for the production of a black oxide film on an iron or steel surface by immersion in an alkaline solution containing an oxidizing agent.

Chemical Affinity. The force which binds atoms together in molecules.

Chemical Change. A rearrangement of elements, atoms or molecules into chemically different identities.

Chemical Compound. A substance composed of two or more elements combined in definite proportions by weight, the individual properties of the constituents having disappeared.

Chemical-Conversion Coating. A protective or decorative coating produced *in situ* by chemical reaction of a metal with a chosen environment.

Chemical Element. (See ELEMENT.)

Chemical Energy. The energy liberated in a chemical reaction.

Chemical Equation. A symbolic representation of a *chemical reaction* showing the relation between the reacting substances and the products, e.g.:

$$Zn + 2HCl = ZnCl_2 + H_2$$

Occasionally this definition is extended to include the heat evolved during the reaction. (See HEAT OF REACTION.)

Chemical Equilibrium. That stage in a chemical reaction when balance is achieved, i.e. when the original substances are reacting at the same rate as the new substances are reacting with each other to form the original substances.

Chemical Equivalent. The weight of an element or radical that will combine with or displace 8 parts by weight of oxygen or 1 part of hydrogen, i.e. the atomic weight of an element divided by its valency.

Chemical Formula. The representation by chemical symbols of the composition of a chemical compound, i.e. NaCl represents sodium chloride or common salt.

Chemical Reaction. The change from one substance to another, brought about by the rearrangement of atoms when two or more elements or compounds are brought into contact under given conditions, e.g.:

$$Zn + 2HCl = ZnCl_2 + H_2$$

Chemical Symbol. A single capital letter, or a capital letter followed by a small one, used to represent an atom of a chemical element, e.g. Fe is the chemical symbol for iron.

Chemiluminescence. The emission of light during a chemical reaction.

Chemisorption. *Adsorption* depending on the chemical attraction between a metal surface and a gas.

Chempure Tin. Commercially pure tin containing a minimum of 99·9% Sn.

Chenot Direct Processes. About 1850, Chenot developed two methods for the direct production of iron. In one method, ore and charcoal were charged into an upright walled retort, around which ran channels in the masonry of the wall. Through these channels hot combustion gases were passed from separate fireplaces. Below each retort was a water-cooled cooler in which the spongy iron was allowed to cool out of contact with air. Reduction required 3 days and cooling the same length of time, hence each charge occupied 6 days. In the second method, ore only was charged into the vertical reduction shaft, and was reduced by producer gas passed into the shaft.

Chesterfield Process. A term often applied to a method of producing stainless steel tubes by the extrusion process, using graphite as lubricant.

Chevenard Micro Tensile Tester. An instrument designed for testing materials of very low strength or of small dimensions. Two interchangeable optical tripods utilizing a light beam and photographic recording, provide the utmost sensitivity in the measurement of elongation and the recording of stress-strain curves. Specimens can be tested dry or in a liquid bath and may be from 2 to 150 mm. (0·08 to 6·0 in.) between grips. The grips will accommodate specimens up to 6 mm. (0·24 in.) wide. A micrometer and accessories are included for carrying out load-elongation cycles between two given values of elongation. (A. 30.)

Chi Phase. (χ.) A constituent found in steels of the 18% chromium, 8% nickel, 3% molybdenum type. It appears to be closely related to *sigma phase* and the X-ray pattern shows it to have a structure either identical or similar to that of alpha manganese. (A. 43.)

Chicken Wire Network. (See CROCODILE SKIN.)

Chile Bar. A copper bar, weighing about 200 lb., the copper being of only about 98% purity.

Chile Saltpetre. Commercial sodium nitrate found in deposits in Chile and Peru.

Chilian Mill. A grinding mill used for crushing ores. It employs heavy rollers running on a circular base plate.

Chill. (*a*) The iron surface of a mould, sometimes water-cooled, which cools

the molten steel rapidly and thus produces a hard surface on the casting. (*b*) That part of the ingot below the feeding head. (*c*) A piece of iron or steel of suitable size and shape placed in the wall of a *foundry mould* to conduct the heat from the thicker parts of the casting, ensuring a more even cooling of the whole, thus preventing the development of unequal stresses. It is used also where portions of the casting are required to be hard. (*d*) In cast iron castings, an external zone of hard *cementite* containing no appreciable *graphite*.

Chill Cast Pig. *Pig iron* cast into metal moulds or *chills*; if a machine is used the product is known as machine cast pig. (A. 26.)

Chill Casting. A casting made in a mould which is capable of rapidly extracting the heat, e.g. an iron mould.

Chill Cracks. (See FIRE CRACKS.)

Chill Crystals. Small crystals of ill-defined structure found in a very thin layer in the extreme outer skin of a steel ingot which has been cast in a *chill*, i.e. cast iron *mould*. They are formed by the rapid freezing of molten metal when it comes into contact with the surface of the mould.

Chilled Iron. *Cast iron* in which the carbon is retained in the combined form in certain areas sufficient to form a *mottled* or *white* structure due to conditions which accelerate cooling to the extent that normal *graphitization* is prevented in those areas, i.e. it is cast in moulds constructed wholly or partly of metal, so that the surface of the casting is white and hard, while the interior is grey. (A. 28.)

Chilled Moulds. *Permanent moulds* of *cast iron* used when large numbers of the same type of castings are required.

Chilled Roll. A typical chilled roll consists of a hard outer layer of white or chilled iron containing approximately 3% carbon and having a hardness of 400 to 500 Brinell. Immediately underlying the hard outer shell, the depth of which is varied according to the user's specification, is a transitional layer of *mottled iron*, of a thickness approximately the same as the chilled outer layer. Finally, the core of the roll consists of full grey iron. (W. 75)

Chilled Spring Wire. Wire drawn from quenched and aged mild steel.

Chilled Work. Castings made in a *chilled mould*. (P. 1.)

Chimneying. (*a*) An irregularity in *blast furnace* operation caused by a segregation of the coarser material in the centre of the furnace, causing the hot gases to ascend through the more open centre with a correspondingly slower movement through the finer material near the walls. (*b*) The effect of the opening round the electrodes where it passes through the roof of an *electric furnace*. This is also known as chimney effect.

China Clay. (See BALL CLAY.)

Chipping. A method of removing surface defects from *blooms*, *billets*, *slabs* and similar semi-finished steel products, or of fins and other excess metal from castings by means of a pneumatic chisel, or other suitable tool.

Chipping Hammer. A hammer with pointed or chisel-shaped faces used for removal of *slag* or *seams* (*deseaming*), or other surface defects.

Chipping Mark. An indentation resulting from chipping in preparation or dressing of a weld. It is shown as a dark shadow of corresponding shape in a radiograph.

Chipping Out. The process of removing slag and other residues from the lining of the *cupola* or furnace after a *heat* has been run. (A. 26.)

Chisel Edge. In a twist drill, the edge formed by the intersection of the flanks.

Chisel Edge Corner. The corner formed by the intersection of a lip and the *chisel edge*.

Chloanthite. (*White Nickel.*) This mineral is essentially nickel arsenide, but cobalt is usually present together with some iron. (See SMALTITE.)

Chlorination. (*a*) The roasting of prepared ore in contact with a chloride, usually common salt, to convert certain metals into the more easily separated chloride. (*b*) The degassing or purification of molten metals by fluxing with chlorine.

Chlorine. (*Cl.*) *Atomic weight* 35·457. A gaseous element belonging to the *halogen series*. It is a highly reactive element and is also a powerful oxidizing agent.

Chocks. Bearings which support the ends of the rolls in a *rolling mill* and thus allow them to be turned without displacement.

Chrichtonite. (See ILMENITE.)

Chromalloy Process. A method in which a surface layer or case of either high chromium, or high chromium carbide content is produced by packing the parts in a patented powdered compound containing chromium, an energizer and an inert material, and heating in a hermetically sealed retort. (S. 36.)

Chromated Protein Film Process. A method for the protection of steel, zinc, aluminium, and brass from corrosion. Either casein, albumin, or gelatin is applied to the metal surface by dipping. The film is then impregnated with chromate by adding the salt to the

protein solution or by separate immersion. This acts as an inhibitor of corrosion and hardens the film. (B. 84.)

Chromatic Aberration. The effect caused by the difference in the index of refraction for light of different wave-lengths, which renders it impossible by means of a simple lens to focus at a single point light from the same source but of varying wave-lengths. (Cf. ACHROMATIC.)

Chromatography. The separation of components in liquid phase by differences in rate and length of *adsorption.* (See CHROMOGRAPH.) (H. 21.)

Chromatometer. A device for measuring the degrees of colour.

Chrome Carbides. (*a*) Materials containing approximately 70% chromium, and having high resistance to abrasion, erosion and corrosion. Their coefficient of thermal expansion is approximately the same as that of steel, and they possess resistance to oxidation, even at high temperatures. (M. 41.) (*b*) Various carbides of chromium found in chromium steels.

Chrome Carburizing. The process consists in passing over the surface of iron or low carbon steel, heated to a suitable temperature, a gaseous mixture of chromous chloride or chromic chloride and a suitable hydrocarbon such as methane, propane or butane. A hardened case is produced very rapidly. (A. 14.)

Chrome Iron Ore. *Chromite.*

Chrome Ironstone. *Chromite.*

Chrome Magnesite Bricks. Special refractory bricks used in the construction of basic furnaces. Such bricks possess considerable resistance to thermal shock associated with high refractoriness under load.

Chrome Ore. *Chromite.*

Chrome X. A mixture of ferrochromium, carbon, silicon and an oxidizing agent, sodium nitrate. It will react exothermically when added to molten iron and steel. For ladle additions, the optimum results are obtained by adding Chrome X in the bottom of the ladle before tapping. Oxidation of the silicon produces sufficient heat to raise the temperature of the reaction products to steelmaking temperatures. This method overcomes the objection of chilling resulting from large additions of cold material to the metal. (G. 40.)

Chromel. An alloy consisting of about 90% nickel and 10% chromium. (See CHROMEL-ALUMEL COUPLE.)

Chromel-Alumel Couple. A *thermocouple* consisting of a positive wire of *Chromel* and a negative wire of *Alumel.*

Chromizing. The production of a corrosion- and heat-resisting surface by the diffusion of chromium into iron and steel. There are several processes of chromizing. When using liquid medium the metal to be treated is immersed in a salt bath containing chromium chloride and a diluent such as barium chloride at a temperature of 1100° to 1200° C. In gas chromizing, chromium chloride vapour is used. In four hours at 1000° C. a layer 0·15 mm. thick is attained containing 35% chromium on the surface and 8% at a depth of 0·1 mm. A low carbon steel is essential. In Germany special chromizing steels have been developed—the *IK* (i.e. *Inkromierung*) steels, containing carbide stabilizers, such as titanium. (See also FOLLSAIN and FLUORIDE PROCESS.) The properties of chromized coatings depend on the composition of the steel, and in particular, on its carbon content. (G. 14.)

Chromite. ($FeO.Cr_2O_3$.) (*Chrome Ore, Chrome Iron Ore, Chrome Ironstone.*) The principal mineral for the supply of chromium. Theoretically it contains 68% of chromic oxide (Cr_2O_3), and 32% of ferrous oxide (FeO), but it is rarely, if ever, found in the pure state, the majority of commercial ores containing about 40% to 55% of Cr_2O_3. A further use of this mineral is for the production of refractory chromite bricks for furnace linings. Owing to the neutral chemical properties of chromite, such bricks are not only resistant to high temperatures, but also to attack by both acid and basic slags. (A. 24.)

Chromium. (*Cr.*) *Atomic weight* 52·01. *Specific gravity* 7·19. *Melting point* 1900° C. A bright silver metal which is relatively hard and brittle, the hardness depending, however, on its method of preparation. Chromium is strongly resistant to atmospheric and other oxidation. It alloys with other alloying elements and with steel over a wide range of proportions. As an alloying element in steel, chromium increases the hardenability and in association with high carbon gives resistance to abrasion and wear. In structural steels it is normally present in amounts up to about 3%. Simple chromium-carbon steels are used for ball-bearings having high elastic limit and high uniform hardness due to the uniform distribution of the hard carbide particles, but for most structural purposes chromium is used in conjunction with up to 4% nickel and small amounts of molybdenum or vanadium. Chromium magnet steels contain up to 6% chromium. Chromium is unique in its effect on resistance to corrosion and scaling and is an essential constituent in all *stainless steels,* e.g. stainless cutlery steels con-

tain 12% to 14% chromium, whilst in steels of the austenitic *corrosion-resisting* type, 18% chromium is associated with 8% nickel, and small amounts of other elements. In *heat-resisting steels*, chromium is present in amounts up to 30%, and it is an important element in many of the highly alloyed heat and electrical resistant materials, whose iron contents are so low that they may be regarded as non-ferrous alloys. The high wear-resistance resulting from the presence of chromium carbides renders steel with high chromium content suitable for die blocks and press plates. Chromium is also used as an alloying addition to high duty cast irons. (O.18.)

Chromium Carbide. (Cr_3C_2.) (See CHROME CARBIDES.)

Chromium Impoverishment Theory. A theory suggested to explain the occurrence of *intercrystalline corrosion* in austenitic *corrosion-resistant steels*. It is based on the supposition that, on holding the steel within certain temperature ranges, chromium carbides are formed within the grain boundaries, and that the chromium content of these carbides is so disproportionately high that they impoverish the surrounding area of its chromium content, thus lowering the chromium content of that area to a composition at which it is no longer stainless and is thus susceptible to corrosion.

Chromoferrite. (See FERROFERRITE.)

Chromograph. A device for making confined spot tests on reagent papers, whereby ions in solution may be estimated. It is used to confine areas of definite size on a strip of reagent paper fed through the apparatus and to control automatically the rate of flow of a measured volume of test solution through the confined spot. (See also CHROMOGRAPHIC CONTACT PRINTING.) (S. 136.)

Chromographic Contact Printing. A rapid means of making complete qualitative analyses of metallic minerals, metals and alloys. In the simple contact print method, gelatine-coated paper impregnated with a selective attacking reagent is pressed against the polished specimen, which may be unmounted or embedded in a mounting medium. The paper is then developed in an appropriate specific reagent, which is sensitive to a particular element, and thereby yields a coloured print showing the distribution of that element throughout the entire area of the polished section. A similar technique is followed in the *electrographic contact print method*, although this involves the passage of an electric current through the specimen. The electrographic process, which is applied to the investigation of conducting minerals, is more rapid and provides prints of greater clarity and sharpness. Both procedures yield pictorial records that can be preserved indefinitely. (W. 50.)

Chrom-X. (See CHROME X.)

Chronak Chromating Process. In this method, a zinc-coated steel surface, after degreasing, is dipped first into warm water and then into a solution containing 200 grams of sodium dichromate, and 6 to 9 ml. of sulphuric acid per litre. After an immersion of from 10 to 30 seconds it is rinsed and dried rapidly. This treatment increases resistance to steam and salt spray but not to atmospheric corrosion. (A. 41.)

Chronograph. (*a*) An instrument recording time with extreme accuracy. (*b*) An instrument for the determination of the position, velocity and deceleration of a small-arms projectile during the course of its penetration through armour plate. (M. 82.)

Chrustiov's Hardness Scale. A scale which it is claimed completes *Mohs' scale* in the region of high hardness, e.g.:

Mineral	*Mohs' Number*	*Chrustiov's Number*	*Mineral*	*Mohs' Number*	*Chrustiov's Number*
Talc	1	0·9	Feldspar	6	6·5
Gypsum	2	2·3	Quartz	7	7·3
Calcite	3	3·3	Topaz	8	7·9
Fluorspar	4	4	Corundum	9	8·9
Apatite	5	5·7	Diamond	10	15·1

(E. 73.)

Chrysler Bearing Test Machine. The machine consists of a main shaft mounted in two main bearings, which are 18½ in. between centres. On this shaft, between the main bearings, are eccentrically mounted two pairs of weights, spaced about 3 in. apart. These, together with the corresponding counterweights located near the ends of the shaft, tend to bow the shaft, the bowing force rotating with the shaft. The bowing action is restrained by the fact that a pair of connecting rods are assembled, with bearings, around the shaft, or around a sleeve mounted on the shaft, and that the small ends of these rods are fixed, being fastened to a massive base or anchor block. The major part of the stress generated by the centrifugal force of the two central pairs of eccentric weights is thus carried by the connecting rods, and in reaching them, it passes through the bearings. When the purpose of the test is to study compatibility of a bearing material with the crankshaft, a sleeve of material and hardness similar to that of the crankshaft is used. When bearing fatigue is

the main question, a hardened sleeve of more durable surface is employed. The machine normally operates at 4000 r.p.m. after 4 hours of a run-in schedule, 1 hour each at 1800, 2800, 3250 and 3750 r.p.m. (J. 19.)

C.H.U. Abbreviation for *Centigrade heat unit.*

Chubb Welding. (See PERCUSSION WELDING.)

Chucks. Small bars set between *flask bars*, to secure the sand in the *cope.*

Churning. The operation of feeding molten metal into a casting with an iron rod, when the metal is solidifying.

Chyometer. An instrument for measuring liquids. It consists of a piston moving in a tube in which the liquid is contained. The quantity expelled is indicated by graduations upon the piston rod.

Ciferri Process. A process used for the construction and repair of open hearth burner ports. It consists of the preparation of a special silica paste which is poured between the damaged surface and a metal form and tamped into place whilst the furnace is still hot. (C. 26.)

Ciment Fondu. (*Bauxite Cement.*) A French cement containing about 44% alumina, 40% lime, 10% silica, and 3·5% of metallic iron with small amounts of magnesia and ferrous oxide. It is claimed to be resistant to the action of sea water.

Cinder. (*a*) The name frequently given to *slag* in *blast furnace* practice. (*b*) The silicate of iron produced as a by-product in the *puddling furnace.*

Cinder Heat. (See WASH HEATING.)

Cinder Notch. The opening in a *blast furnace* designed for the removal of the *slag.* It is situated above the *iron notch* or *tap hole.* The notch is protected by a series of water coolers, the outer one, that of largest diameter, being known as the *cooler,* inside this is the *intermediate cooler,* whilst within this is a still smaller cooler known as the *monkey,* which reduces the opening to about 2 ins.

Cinder Patch. A scab-like surface defect caused by the adhesion of scale from the bottom of the soaking pit to the surface of the ingot.

Cinder Pig. Pig iron produced by re-working *cinder.* Such pig iron is of very inferior quality.

Cinnabar. A sulphide of mercury (HgS); the only known ore of mercury.

Circular Inch. The area of a circle whose diam. is 1 in. = 0·7854 sq. in.

Circular Mil. The area of a circle whose diam. is 1 mil. (0·001 in.). It is the unit used for the measurement of the cross-sectional area of wires.

Circular Mil Gauge. (*Edison Gauge.*) A gauge based on the *circular mil.*

Circular Seam Welding. *Transverse seam welding.*

Circumferential Seam Welding. *Transverse seam welding.*

Cire Perdue Process. (See LOST WAX PROCESS.)

Cl. Chemical symbol for *chlorine.*

Clad Steels. (See CLADDING.)

Cladding. A process of bonding two dissimilar metal sheets or plates, the covering metal usually possessing greater corrosion resistance. For example, mild steel may be clad with stainless steel, as in *Ingaclad* and the *Pluramelt Process,* or *duralumin* may be covered with pure aluminium as *Alclad.* Various methods are used: (i) casting, (ii) inter-melting, (iii) fusion welding, (iv) arc welding, (v) resistance welding, and (vi) bonding, using heat and pressure. By far the greatest tonnage is produced by method (vi) in which a pack or sandwich is prepared by placing together two pairs of plates, each pair consisting of a carefully cleaned base plate and a sheet of the nickel, nickel alloy, or stainless steel on top of it. The pairs are placed with the two sheets of cladding material face to face but separated by an infusible parting compound. The edges of the pack are sealed by welding: it is then heated to 1150° to 1300° C. depending on the cladding, and rolled out in a heavy plate mill. On cutting off the sealed edge the two clad plates can be separated. (P. 12.)

Clamp Off. An indentation in the casting surface, due to displacement of sand in the mould. (A. 26.)

Clamping Bar. A bar used to tighten the *clamps* on a *mould.*

Clamps. Devices for fastening *copes* and *drags* together.

Clarendon Laboratory, Oxford. The original Clarendon Laboratory, built in 1872, was the first laboratory in the world specially designed for the study of physics. The Electrical Laboratory was added in 1910 and the present laboratory was completed in 1940. The chief lines of investigation include nuclear physics, low temperature physics, spectroscopy, and electrical phenomena in gases.

Clark and Freeman Sliding Wear Test. An accelerated sliding wear test in which the wear-resistance of a metal surface is determined by the magnitude of the force required to produce a scratch in conjunction with the width of the scratch made by a diamond of known dimensions. (C. 29.)

Clark Cell. A standard cell for the measurement of electrical potential.

Mercury and zinc amalgam electrodes are employed in an electrolyte consisting of a solution of zinc sulphate.

Classification. The separation of a powder into fractions according to particle size. (G. 30.)

Claus. (or Klaus.) (1796–1864.) A Russian chemist and the discoverer of ruthenium, 1845.

Clay. A hydrous silicate of alumina, more or less mingled with mineral impurities and coloured by metallic oxides and organic matter. Pure clay is an earth which possesses sufficient ductility and cohesion, when kneaded with water, to form a paste capable of being fashioned by hand, and of resisting heat. (A. 26.)

Clay Gun. A device for ramming clay into tapholes.

Clay Ironstone. (Argillaceous Haematite.) An iron ore consisting of oxide with clay or sand, and sometimes other impurities.

Clay Substance. (*A.F.A. Clay.*) The earthy portion of foundry sand which, when suspended in water, fails to settle 1 in. per minute and which consists of particles less than 20 microns (0.02 mm. or 0·0008 in.) in diameter.

Clay Wash. Clay diluted with water to a creamy consistency and used for various purposes in the foundry.

Clayband Ironstone. An iron ore, consisting of carbonate of iron mingled with clay, found in the coalfields of Yorkshire, Derbyshire, Staffordshire and South Wales. It has an iron content of about 30%.

Clayed Up. (See BRICKING UP.)

Clean Steel. Steel containing a minimum quantity of *non-metallic inclusions.*

Cleaner. A moulding tool used for smoothing flat, narrow surfaces.

Clearance Angle. (See RAKE.)

Cleavage. A term used in crystallography to denote direct separation of the material on crystallographic planes called *cleavage planes*. Such separation is evidenced in the fracture of polycrystalline metals by a sparkling crystalline appearance. Cleavage cannot occur in non-crystalline materials. It can occur in metals after considerable deformation, and should not, therefore, be confused with absence of ductility. (B. 75.)

Cleavage Fracture. A fracture along the *cleavage planes* characteristic of a *brittle fracture* and showing little plastic deformation.

Cleavage Planes. Planes of easy fracture where cleavage usually occurs when the crystal is subjected to stress parallel to one or more of the faces of the system to which the crystal belongs. They are not necessarily related to the boundaries of the crystal, and are found in both minerals and metals.

Cleavage Tear Test. (See BAGSAR.)

Cleveland Cup. (See FLASH POINT.)

Cleveland Ores. *Spathic ores* occurring in North Yorkshire.

Clink. A crack, either internal or external, caused by uneven contraction or expansion during heating or cooling of steel.

Clinked Ingot. An ingot containing *clinks*. These may arise from two different causes: (1) Too rapid heating, which results in the centre of the ingot being unable to withstand the tension set up by the expansion of the outer portion of the ingot, thereby giving rise to internal rupture; (2) too rapid cooling of ingots after stripping the ingot mould which results in the rapid contraction of the exterior of the ingots. (B. 22.)

Clinker. Fused residual ash from coal or coke fired furnaces.

Clip. (See CEMENTATION.)

Clipping. Trimming the rough edges from sheet metals, as, for example, by stamping or drawing.

Close Annealing. (See BOX ANNEALING.)

Close Bend. (See BEND TEST.)

Close Joint. A joint where the surfaces to be welded are substantially in contact during the welding operation.

Close Joint Tube. Tube made from strip which is formed into the desired diameter, the edges being brought together but not welded.

Close Packed. Concerning atomic arrangement in crystals. Having one of the two possible arrangements, one cubic and one hexagonal, in which equal hard spheres can be made to occupy the least total volume; and, by extension, having any of the hexagonal arrangement derived from the second of these by expansion or contraction of the hexagonal axis. (See FACE-CENTRED and CLOSE-PACKED HEXAGONAL.) (A. 27.)

Close-Packed Hexagonal. An arrangement of atoms in crystals which may be imitated by packing spheres. It refers to a prismatic unit cell having a base in the form of a rhombus with 60° and 120° angles and a height that approaches, ideally, 1·63 times the length of an edge of the base. It has a lattice point at each corner. In metallic elements based on this lattice, an atom lies at each corner and another atom, not on a lattice point, is located at half height directly above the centre of one of the two equilateral triangles into which the base may be divided. (See SPACE LATTICE.)

Close Plating. The application of a thin sheet of metal by *soldering.*

Closed Box Pass. The type of pass produced when the grooves in a pair of rolls are so shaped as to form a square or rectangle, i.e., a completely closed cross-section.

Closed Die Coining. (See COINING.)

Closed Die Forging. This process may be carried out either by the use of hammers, forging or upsetting machines, or presses. In each case force is applied in such a way as to cause the heated metal to be hammered or pressed into a cavity in a split die. One part of the die is mounted on the stationary member of the hammer, press or forging machine, and the other part is mounted on the moving member of the equipment. Heated stock is placed between these dies and the force applied by the moving die causes the metal to fill the die cavity. (K. 57.)

Closed Flash Point. (See PENSKY MARTENS FLASH TESTER.)

Closed Top Housing. A *housing* for a stand of rolls in which the base, top, and legs consist of a single unit.

Closed Top Furnace. A blast furnace closed at the throat for the purpose of collecting the gases.

Closing. Reducing the diameter of a hollow forging or tube by pressing or hammering on a mandrel.

Closing In. The further forging operation conducted on the ends of hollow forgings to develop a nozzle section. It usually involves one or more local reheatings. Flat, tapered, curved or formed dies are used.

Cloth. The term as used in *powder metallurgy* refers to metallic or non-metallic fabric used for screening or classifying powders.

Cloth Rolls. Cloth-covered rolls used to remove the last traces of oil from the surface of *terne* or *tin plate*.

Clotting. The partial fusion of ores during roasting.

Cloud Points. (See POUR AND CLOUD POINTS.)

Cloudburst Hardness Testing Machine. Apparatus for the determination of soft spots in hardened surfaces. Hard steel shot is allowed to cascade on to the surface and soft spots show up as dull matt areas in the bright hard surroundings. These machines are of two types, the gravity type, in which the velocity of the balls is controlled by the height of their fall, and the deflector type, in which the velocity depends on the speed of the rotor which sets the balls in motion. (H. 41.)

Cloudburst Steel-Hardening Process. A method of super-hardening steel by bombarding the surface with hard steel balls which are caused to strike the steel with predetermined and controlled velocity. (H. 42.)

Cluster Centrifugal Casting. (See CENTRISPINNING.)

Cluster Mill. (See ROLLING MILLS.)

Clyde Alloy Steel Co. Inclusion Estimation Method. In this method the inclusions are counted and their length is measured, and the statement of results gives the length of inclusions per square inch of steel, the average length of the inclusions and the length and approximate thickness of the largest inclusion. (H. 84.)

C.M.P. Controlled Materials Plan, administered by the National Production Authority, an agency in the U.S.A. Department of Commerce. (S. 128.)

C.N.R.M. Centre National de Recherches Metallurgiques.

Co. Chemical symbol for *cobalt.*

CO. *Carbon monoxide.*

CO_2. *Carbon dioxide.*

Coal Dust. A material frequently used in sand moulding. For all classes of work, the coal should be of fine grain and the volatile material should not be less than 28%. A correct proportion of coal dust mixed with the sand is stated to improve the skin of the casting and promote clean stripping by imposing a carbon film between the molten metal and mould face. It assists in preventing sand scabs, and produces a more refractory sand by coating the grains with a carbon deposit. (H. 61.)

Coal Oil. (See KEROSENE.)

Coal Tower Reheating Furnace. In this furnace which was developed in Sweden, the coal is fed from the hopper or tower by an archimedian screw and the air supply is preheated in a steel recuperator. (W. 7.)

Coalescence. The union or growing together of crystals or globules due to molecular attraction.

Coarse Crystallization. This results from high temperature casting and slow crystallization. Such ingots should be carefully reheated and forged gently, or they may develop corner cracks.

Coarse Grains. (See AUSTENITIC GRAIN SIZE.)

Coated Electrode. (*Covered Electrode.*) An electrode consisting of a metal core, usually cylindrical in form, covered with a mixture probably of organic and mineral substances, but which may vary widely in composition according to the results required.

Coated Particles. Metal particles whose surfaces have been covered with another metal.

Coating Thickness Meter. An instrument for measuring the thickness of coatings of non-ferrous metals, paints

and enamels on a ferromagnetic base, consisting of a cylindrical case, about the size of a pencil, containing a movable bar surrounded by a light coil spring. The bar carries a permanent magnet at one end which projects beyond the case and has fixed to it a spherical shoe of high-permeability material. The bar is notched at suitable intervals and a spring catch locks it in the extended position on the instant of its removal from the surface. The instrument is held vertically on the coating to be measured and the magnetic force compresses the spring as it extends the bar by an amount depending on the thickness of the coating. (B. 49.)

Coaxing. A method of improving *fatigue resistance* in which the piece is understressed followed by gradually increasing the amplitude of the alternating stress. (S. 71.)

Cobalt. (*Co.*) *Atomic weight* 58·94. *Specific gravity* 8·9. *Melting point* 1492° C. A grey magnetic metal of medium hardness; it resists corrosion, like nickel which it closely resembles. Cobalt is fairly widely dispersed and occurs in many minerals. The most important, from the point of view of the supply of cobalt, are sulphides, arsenides and oxidized compounds. The arsenides are usually found in association with nickel, silver and gold, whilst the sulphide minerals generally occur with copper, although, for example, linnaeite (Co_3S_4) is found among the lead-zinc deposits. In recent years the copper mines of the Belgian Congo and Northern Rhodesia have supplied more than 80% of the world production of cobalt, the only other important producing countries have been Canada, French Morocco and U.S.A. Cobalt raises the red hardness of steel and this is the reason for adding 5% to 10% of this metal to certain types of *high-speed steels*, developed for the specific purpose of cutting exceptionally hard materials. *Heat-resisting* alloys with high cobalt contents have been developed for use in turbine engines. Cobalt is added to the extent of up to 40% to *magnet steels* requiring high coercive force and it is used in electrical-resistance alloys. In the sintered *hard metals*, cobalt is an essential constituent as it acts as the binding metal. (Y. 7.)

Cobalt Glance. (See COBALTITE.)

Cobaltite. (*Cobalt Glance*) A sulpharsenide of cobalt, $CoS_2.CoAs_2$. It takes its name from the deposits found in the district of Cobalt in Ontario, Canada. Other deposits are found in Sweden, Norway and India.

Cobble. A defect which results in undue distortion in a rolled piece, and usually leads to rejection. Although the distortion may take various forms it is due essentially to loss of control during the course of a pass. It may occur in either hot- or cold-rolling and at various stages, e.g. by the twisting of the bloom in the cogging mill or in the bar mill when a bar misses the guide. In a plate mill, the cobble may take the form of a plate with a bent end due to the piece having followed the contour of the roll, whilst in cold rolling it may appear as uneven extensions of the sheet or strip.

Cockles. (*Riffles.*) Uneven edges on sheet metal.

Cocoa. (See FRETTING CORROSION.)

Cocoon Process. A method developed for the protection of metal parts during shipment or storage. The article to be covered is surrounded by a grid of tape —not touching the metal. The grid is filled in with cobweb-like filaments from a spray gun, and the whole coating is reinforced by several layers of a plastic film also sprayed from a gun. (F. 20.)

Cod. A portion of the *drag* which may extend into the body of the mould and thus function as a *core*.

Codorous Ore. A highly siliceous haematite containing only a trace of phosphorus, but high in potash.

Coefficient of Corrosion. The reciprocal of anode corrosion efficiency. A term used in applied cathodic protection.

Coefficient of Elasticity. (See *Elasticity, Young's Modulus, Shear Modulus* and *Bulk Modulus.*)

Coefficient of Expansion. The ratio of the change in length, area, or volume per degree to the corresponding value at a standard temperature, usually 0°C.

Coefficient of Friction. In rolling, the non-dimensional ratio between the force required to cause relative motion at constant speed between two surfaces, and the normal force pressing the surfaces together.

Coefficient of Magnetic Induction. (See PERMEABILITY.)

Coefficient of Magnetization. (See SUSCEPTIBILITY.)

Coercive Force (*Hc*). The magnetizing force required to bring the induction to zero in a magnetic material which is in a symmetrically cyclically magnetized condition. *Intrinsic coercive force* (*Hci*). The magnetizing force required to bring to zero intrinsic induction of a magnetic material which is in a symmetrically cyclically magnetized condition. *Relaxation coercive force.* The reversed magnetizing force of such a value that, when reduced to zero, the induction becomes zero. (A. 28.)

Coercivity. That property of a material measured by the maximum value of the coercive force. (A. 28.)

Coffin Annealing. (See Box Annealing.)

Coffin Process. A method of promoting grain refinement and toughness in steel parts, e.g. axles, which consists in heating to a temperature slightly above the upper critical point, quenching in oil to the lower critical point, followed by air cooling.

Cogging. (*Roughing.*) The action of reducing a white hot ingot to blooms or slabs. It is the first stage in forging or rolling. An ingot which is reduced under a hammer is said to be *hammer cogged* to distinguish it from one reduced under a pair of rolls in a *cogging mill*, which is said to be *roll cogged.*

Cogging Hammer. A forging hammer used to reduce ingots to *blooms* or *billets.*

Cogging Mill. (*Blooming Mill.*) (See also Rolling Mills.)

Coheracle Test. (See Schnadt Test.)

Cohesion. The force by which particles are held together. It varies with different metals and depends upon hot and cold working as well as upon molecular arrangement due to heat treatment. (A. 26.)

Cohesive Strength. A term used with one of the following meanings: (1) The *maximum stress* required in order to cause tensile fracture in the absence of any deformation, when two of the three principal stresses equal zero, i.e. with an unnotched bar; sometimes called *initial cohesive strength.* (2) The maximum principal stress required in order to cause tensile fracture when tri-axial stresses are present; i.e., by using a *notched test bar.* This is frequently called the *technical cohesive strength,* and is variable, depending on the relative magnitude of the three principal stresses, the amount of plastic deformation preceding fracture, and the temperature and rate of straining. (3) (See Disruptive Strength.) (A. 27.)

Coil Breaks. (See Cross Breaks.)

Coin Dimpling. A pressing operation. combining *drawing* and *coining.* It is a refinement of the radius dimpling method of countersinking rivet holes which are drilled in sheet metal in order that the rivet heads may be approximately flush with the surface. (A. 17.)

Coining. (*a*) A process of forming metals, in which the metal is shaped, usually in the cold state, between two dies in such a manner as to fill the independent depressions of both dies in relief, by displacement of the material. In practice, it is usual to distinguish between coining and *embossing.* Embossed work can be recognized by the fact that the reverse of the piece is the exact negative of the obverse. The method is suitable for work in high relief. The depth of the depression is often many times the thickness of the relatively light-gauge sheet metal ordinarily used for such work. Embossing is used when only one side is intended to be visible, the impression being then given of a heavy solid article. In embossing, the material has to be stamped between the two reliefs of the dies (upper die positive, bottom die negative) and then drawn to fill the depressions of the bottom die. Coining finally impresses the finest details of the design, and gives a sharp relief. In *full coining,* the characteristic feature is the swaging or upsetting of the material between the two halves of the die. This action causes plastic flow of the material outward and into the depressions of the die. If the outward flow of material between the two halves of the die is not prevented, a flash or fin is formed (*open die coining*). In *closed-die coining,* the two halves of the die are movably enclosed in a ring or cylinder. The material is thus prevented from flowing outward, and is constrained to fill all remaining cavities or depressions in the die. (H. 79.) (*b*) For the term coining, as used in *powder metallurgy.* (See Sizing.)

Coining Dies. Dies used for *coining* or *sizing* operations.

Coke. The solid residue from the carbonization of coal after the volatile matter has been distilled off. It is used as a fuel, and in metallurgy as a reducing agent for metal oxides. *Gas coke* is produced by the carbonization of bituminous coal in a closed chamber known as a retort, the temperature of the charge ranging up to 1100° C. Low-temperature coke has a much higher percentage of volatile matter than gas and metallurgical cokes, and a lower percentage of fixed carbon. Metallurgical coke is a dense coke suitable for *blast furnace* and *foundry use.*

Coke Bars. Small slabs used for the production of tinplate.

Coke Breeze. The smaller grades of coke from coke ovens or gas-works, ⅝ in. or under, used in the manufacture of breeze concrete, and for partition walls.

Coke Hole. (See Crucible Process.)

Coke Mill. A mill used in the foundry for the grinding of coke for the production of blacking.

Coke Oven Gas. Gas produced in the manufacture of hard coke from hard-caking bituminous coal; *calorific value* per cubic foot, at 15° C., is about 520 *B.Th.U.*

Coke Ovens. Large ovens in which hard-caking bituminous coal is subjected to a long process of carbonization at high temperatures.

Coke Tinplate. Hot dipped tinplate having an unspecified minimum weight of coating.

Colbond. A finely ground plastic clay imported from Eire. It is added to moulding sands to give the required workability.

Colby Furnace. An early form of induction furnace (1890) very similar to the *Kjellin* except that it employed a copper tube, through which water was circulated, for the primary coil. The furnace was arranged to tilt in order to pour the charge and was covered with a hood to exclude the air.

Colclad. A proprietary stainless *clad steel.* (C. 46.)

Cold Atrament Process. (See ATRAMENT C. PHOSPHATING PROCESS.)

Cold Bed. (See COOLING BED.)

Cold Bend Test. (*a*) A test for tubes in which a strip not less than 1 in. wide, cut circumferentially from one end of each selected tube, shall, when cold, withstand, without showing either crack or flaw, being doubled over in the direction of the original curvature round a bar of the specified diameter. In the case of welded tube, the test piece shall be cut to include the weld which shall be placed at the point of maximum bending. (*b*) A test for wrought iron chain in which each half link shall withstand being bent cold by pressure or by a succession of blows, without hammering direct on the bend, until the edges of the links are in tight contact, without sign of fracture on the outside of the bent portion.

Cold Blast. Air under pressure which has not been preheated.

Cold Blast Iron. Pig iron, usually having a low silicon content, made in a blast furnace, in which the blast is not preheated. This quality of iron is now seldom made.

Cold Brittleness. Lack of ductility at low temperatures, e.g. *Izod tests* on *Armco iron* show a tough to brittle transition between 20° and −30° C., whilst in tensile tests this transition takes place at a much lower temperature, i.e. between −120° and −180° C. (C. 41.)

Cold Chamber Process. A method of pressure casting in which the molten metal is forced into the die under pressure.

Cold Cracking. Cracks in cold, or nearly cold, metal, due to excessive internal stress caused by contraction. Such cracks may be brought about by the fact that the mould is too hard or by the unsuitable design of a casting.

Cold Drawing. The process of reducing the cross-sectional diameter of tubes or wire by drawing through dies without previously heating the material. (See also BAR DRAWING; MANDREL DRAWING; PLUG DRAWING and SINKING.)

Cold Drawing Die. A block of extremely hard material containing a tapered hole, the smaller end conforming to the final shape and size.

Cold Drawn Bars. (See BRIGHT DRAWN BARS.)

Cold Extrusion. (See EXTRUSION.)

Cold Finishing. A term covering a number of final operations in a steelworks, such as *cold drawing, cold rolling,* polishing, and *straightening.*

Cold Flow Pressing. (See EXTRUSION.)

Cold Galvanizing. A term sometimes used for *electro-galvanizing.*

Cold Heading. A process for making the heads of rivets and bolts by plastic flow in *dies.* Wire stock is used and by the application of pressure on the end of the piece of wire, the diameter is increased and the flow confined in dies. The manner of flow, as indicated by the grain revealed by deep etching, is very important. (See also UPSETTING, FIBRE, COLD-WORKING, PLASTIC FLOW, HOT WORK.)

Cold Inspection. Visual inspection of a forging for the detection of any surface defects.

Cold Junction. (See THERMOCOUPLE.)

Cold Lap. Wrinkled markings on the surface of an ingot representing incipient freezing of the surface of the metal, and due to too low a casting temperature. The surface is liable to contain oxide at the base of the wrinkles and subsequent hot working may lead to *cracks, rokes* or *double skins.*

Cold Melt Process. (See COLD METAL PROCESS.)

Cold Metal Process. (*Cold Melt Process.*) A steel-making process in which the *charge* consists entirely of cold metal.

Cold Pressing. The forming of a *compact* at room temperature.

Cold Rectifying. (See COLD ROLLING.)

Cold Reduction. (See COLD ROLLING.)

Cold Reduction of Tubes. In this process, the tube with a mandrel inserted, but not tagged, is fed forward in a series of steps by hydraulic power. At the end of each forward movement the tube pauses, while the reciprocating head rolls a pair of circular dies over it. The dies each have a groove of constantly decreasing radius and the tube is fed forward when the dies are in a position to present the widest part of the matching grooves to it. As the

dies are rolled forward by the reciprocating head, the narrowing grooves roll the tube down on to the mandrel, so effecting the required reduction in diameter. When the dies have done their work on the length of tube accessible to them, they are rolled back, and the tube is again fed forward into the widest parts of the matching grooves. So the cycle proceeds, until the whole length of the tube has passed through the machine. (E. 62.)

Cold Reeling. (See REELING.)

Cold Roll Forming. A process whereby a flat strip of metal, by passing through a series of rolls arranged in tandem, is progressively formed into the desired shape. The number of rolls required is determined by the character and intricacy of the shape, also the thickness and kind of material to be formed. (V. 3.)

Cold Rolled Sheet. Material over 12 to 24 in., inclusive, in width: 0·0142 in., or over, in thickness, if no special edge finish or temper is specified.

Cold Rolled Strip. (See STRIP.)

Cold Rolling. (*Cold Rectifying.*) (*Cold Reduction.*) The *rolling* of steel below its recrystallization temperature. The term is usually applied to steel rolled at or near room temperatures, with the object of reducing the thickness and providing a smooth surface finish and/or enhanced tensile strength. (See COLD WORK.) Considerably greater accuracy of dimension is attainable as compared with *hot work*.

Cold Sate. (See COLD SETT.)

Cold Saw. A circular steel saw employed in cutting steel bars which are in the cold condition. Usually the teeth are fitted into the saw.

Cold Sawing. Sawing at atmospheric temperatures to specified lengths.

Cold Sett. (*Cold Sate.*) A short chisel with a hardened and tempered cutting edge used for cutting bars without heating. It is held by means of a suitably shaped iron rod bent round a recess in the chisel and is struck by a sledge hammer.

Cold Shaping Steels. Steels which can be cold worked by *cupping*, *drawing*, *coining*, *heading*, *necking* and *extruding* when phosphate coated and adequately lubricated. (S. 125.)

Cold Short. Lack of *ductility* in metals when worked at room or low temperatures.

Cold Shots. Intensely hard pieces of metal, usually globular in shape, sometimes found in otherwise soft and machinable castings. They are generally formed by the first splashes of metal, poured into the mould, which are chilled on striking the cold sand. (P. 9.)

Cold Shut. (*Teeming Arrest.*) (*a*) The freezing over of the top surface of an ingot before the mould has been filled, due to an interruption of the stream of metal. (*b*) A casting defect caused by the non-fusion of metal where two streams meet, leaving apparent cracks or surface wrinkles together with oxide films. Sometimes called *cold lap*.

Cold Side. The term applied when one side of an ingot, bloom, or bar has a lower temperature than the other. During rolling, this phenomenon usually causes the bar to curve.

Cold Sprueing. The removal of the gates from a casting after it has solidified.

Cold Treatment. (See SUB-ZERO TREATMENT.)

Cold Trim. The removal of *flash*, by a shearing operation in a power press while the forging is at room temperature.

Cold Welding. A process in which ductile metals are welded by pressure alone. The pressure is applied to lapped workpieces of sheet metal by specially designed tool dies, mounted in a suitable type of press. Pressures are generally above the flow point of the material and range from about 12 to 18 tons/sq. in. for aluminium and two to four times as much for copper. (E. 25.)

Cold Working. A method of conferring strength by means of plastic deformation below the annealing temperature. This treatment may consist of *cold rolling*, *hammering*, *drawing*, *heading*, *spinning*, *swaging*, or *pressing*, usually at room temperatures. The *hardness* and *tensile strength* are progressively increased with the degree of cold work, whilst the *ductility* and *impact* values are lowered. Where this increased hardness is not desired, the material is annealed at various stages between the cold-working operations or it may be subjected to a final *annealing*. Steels containing 0·7% to 0·85% carbon are often cold worked until they possess a tensile strength of 120 tons/sq. in., while piano wires may attain 150 tons/sq. in. or higher. Polishing and machining also have the effect of cold working the material.

Coli Process. Steel produced in the acid open hearth, when ready for casting, is poured into a receptacle into which is simultaneously poured a basic slag. The process has, therefore, the advantages of both the acid and the basic processes. (C. 45.)

Collapsibility. The tendency of a sand mixture to break down under the conditions of casting. (A. 26.)

Collar. (*a*) The part of the roll barrel which projects after the roll has been turned in the roll turner's lathe. (*b*) The reinforcing metal of a non-pressure thermit weld. (*c*) That part of a forging where the diameter is increased. (*d*) (See GUIDE).

Collar Marks. Defects produced on rolled sections by the *roll collars* scoring the work.

Collaring. The accidental wrapping of the work round the rolls in a rolling operation.

Collecting Electrode. (See PASSIVE ELECTRODE.)

Collet. An externally coned sleeve, slotted along one side and arranged to be drawn into the internally coned nose of a lathe mandrel for the purpose of gripping small circular work.

Collimate. To isolate a parallel, or nearly parallel, beam of rays, as by slits, pinholes or a channel. (A. 27.)

Collins-Oseland Tube. A photo-electric open tube bath pyrometer. The liquid steel is observed through an open tube inserted into the liquid and kept clear by a current of air. The tube is a 6-ft. length of 2-in. steel pipe closed at one end with a heavy glass window and provided at the other end with a steel tip having a central orifice ½ to ¾ in. diam. A side opening connects the pipe to a source of air pressure. With air pressure turned on and air passing freely through the tube, the heavy-tip end with the small orifice is submerged in the liquid iron or steel. A reading is then taken with an optical pyrometer sighted through the glass window on the bright spot outlined by the tip orifice. Readings must be made quickly before the pipe becomes hot enough to bend and before the tip begins to melt in the bath. Although the observer sees only a bright disc of light, the reading actually is being made on the inner surface of a bubble or cavity in the liquid metal. This cavity is not a perfect radiator, because one side of it is cold. Therefore, the optical pyrometer readings must be corrected. (F. 34a.)

Colloid. A substance in the form of ultra-microscopic particles intermediate in character between a true solution and a suspension, but there is no hard-and-fast demarcation between suspensions, colloids and true solutions. Colloids diffuse through parchment extremely slowly. The name colloid is taken from the Greek word "kolla", meaning glue, and as the name suggests, colloidal substances are characterized by the fact that they are extremely difficult to filter.

Colloidal Graphite. (See GRAPHITE.)

Colmonoy Sprayweld Process. (See SPRAYWELD PROCESS.)

Colorimeter. An instrument used to measure the relative intensity of the colour of solutions and thus to determine the quantity of the colouring substance present by comparison with a prepared standard solution.

Colorimetric Analysis. A process whereby the amount of an element present in a solution is determined by measuring the intrinsic colour, or the colour of the reaction product developed when selected reagents are added to the solution. The several means of measuring the colour include visual comparison with solutions containing known amounts of the element sought, and the use of optical instruments capable of determining the absorption or transmission of the solution at selected wave-lengths.

Colour-Brightness Pyrometer. The instrument consists of a telescope with objective lens, eyepiece, and diaphragm. A bichromatic colour wedge is placed in the path of radiation of the body, the temperature of which is required. The grey wedge reduces the brightness of the transmitted beam of radiation. A glass cube, silvered and cemented along a diagonal plane, brings the radiation from the comparison lamp into the same field of view as the main source. The light from the lamp is first filtered by a flat bichromatic plate which transmits only red and green wave-lengths, in such a ratio that the resultant is white. The provision of this standard field of light with a similar spectral distribution to the field under observation is claimed to eliminate the defect of the human element. (H. 34.)

Colour Carbon. (See EGGERTZ TEST.)

Colour Etching. A micro-etch resulting from the formation of a thin film of a definite compound of the metal. Heterogeneity changes the nature or rate of growth of this film, whose thickness or *refractive index* will differ from place to place. Reflected light will produce interference phenomena giving rise to colours, heterogeneity is thus revealed by differences in colour. (B. 27.)

Colour Pyrometer. (See BIOPTEX PYROMETER.)

Colouring. The final stage in the production of a very high polish on metals, the metal assuming a darker hue due to elimination of scattered light. (B. 103.)

Columbite. The most important ore of columbium (niobium) and almost invariably associated with tantalum. If

the tantalum content is higher than the columbium, it is known as *tantalite*. The iron and manganese contents vary widely and tin and tungsten may be present in small amounts.

Columbium. (*Cb.*) (See NIOBIUM.)

Columnar Crystals. Crystals which, during solidification, have grown preferentially in one direction, owing to a sharp temperature gradient, thus presenting a coarse structure of parallel columns of grains.

Columnar Crystal Magnet. A type of sintered magnet developed by the Permanent Magnet Association.

Colza Oil. A rape seed oil used as a lubricant in fine wire drawing.

Combination Core Box. A *core box* that can be altered to form a core of another shape. (A. 26.)

Combination Mill. A rolling mill in which the major reduction is carried out on continuous rolls, only the final shaping being done in the *guide* or *looping mill*.

Combination Quenching. The process of quenching in a bath in which the upper half is oil and the lower half water. The steel is partly cooled in passing through the oil and retains a film of oil which renders the quenching action of the water less drastic.

Combined Carbon. (*C.C.*) Carbon present in steel and cast iron in the form of iron carbide, Fe_3C, as distinct from *graphite* and *temper carbon*.

Combined Water. Water in mineral matter which is chemically combined and driven off only at temperatures above 110° C.

Combining Weight. (*Equivalent Weight.*) The weight of an element or radical which combines with or replaces a unit weight of hydrogen.

Combustion. A chemical change resulting from the combination of an element, acting as fuel, e.g. carbon or hydrogen, with oxygen, the reaction resulting in the development of heat.

Combustion Chamber. The space in a furnace where the combustion of the gaseous products from the fuel takes place.

Combustion Furnace. The term as used in chemical analysis refers to a small, generally, electrically heated furnace, used for the *combustion process*.

Combustion Process. A method for the quantitative determination of carbon, and less frequently of sulphur, in steel. A weighed sample of the millings is placed in the hottest portion of the *combustion tube* which passes through the furnace, and a stream of oxygen passed through. The carbon dioxide formed by combustion of the carbon in the steel is absorbed in a suitable medium and the carbon determined by the increase in weight.

Combustion Tube. The refractory tube, usually of quartz, used in the *combustion process*.

Coming to Nature. The stage in the *puddling process*, when, the carbon having been oxidized, and the bath becomes calm, and the melting point of the iron is raised by the loss of carbon, particles of solid iron form which can then be worked into balls by the puddler.

Commercial Annealing. (See PROCESS ANNEALING.)

Commercial Quality. Steel which is not manufactured to meet any definite specification as regards composition or mechanical properties, but is of sound quality.

Comminution. (See PULVERIZATION.)

Common Drawn Size. (See BASE SIZE.)

Common Substance. (See SUBSTANCE.)

Commutator Controlled Welding. (*Ultra-Speed Welding.*) The making of a number of spot or projection welds wherein several electrodes, in simultaneous contact with the work, progressively function under the control of an electrical commutating device. (A. 37.)

Compact. (*Briquette.*) An object produced by the compression of individual, mixed, or alloyed metal powders with or without the inclusion of non-metallic constituents.

Compact Black Manganese Ore. (See PSILOMELANE.)

Compactibility. The ability of a powder to be formed into a compact of well-defined contours and structural stability at a given pressure; a measure of the plasticity of the powder particles. (G. 30.)

Comparator. An instrument for accurately measuring lengths or checking scales by comparison with a standard scale.

Comparator-Ruling Machine. A device employed in connection with the investigation of the propagation of plastic strain in long wires and used for marking the specimen, before testing, with a scratch made at 1-in. intervals along its length by means of a razor blade. After testing, the distance between the scratches is measured with the aid of a low-power microscope and a graduated dial. The comparator can travel 39 ins. (D. 54.)

Compo. (*a*) A contraction of the name *Sheffield composition*. The term covers the miscellaneous mixture of materials sometimes used for refractories intended to be rammed or daubed into

position in use. The main ingredients are silica sand, crushed firebrick and fireclay or similar material. It varies considerably in analysis, but uniformity of the grain size of the sand and the intimate mixture of the bonding material are essential. (*b*) A proprietary name for a graphite bronze containing about 10% tin and 1·5% carbon in the form of graphite.

Composite Cast Iron Rolls. In casting such rolls, the mould is first filled with the metal, which is to form the outer surface of the roll, and after it has solidified to the required depth, the liquid metal in the centre is displaced by teeming the molten iron of different analysis which is to make the tough core of the finished roll. It is claimed that the surface hardness and the hardness depth can be varied within wide limits and the two metals bond together as one. (D. 6.)

Composite Casting. The term is used to refer to a process by means of which two different materials are bonded by casting and to the casting produced by such a process. In the course of the process it is necessary for one of the materials to be used in the molten state—to enable casting to take place—while the other must be present in the solid or solidifying state in order that an undesirable mixing of the two materials may be avoided. In the non-ferrous industry, the term is usually taken to mean a casting involving the bonding of a non-ferrous metal to iron or steel. The steel in such a case is usually referred to as the basis metal or backing, the layer of non-ferrous metal which is bonded to it being referred to as the coating. Those processes in which iron is brought into contact with a non-ferrous metal by pressing, rolling or forging in the solid state without heating above the melting point must not be confused with composite casting, and are referred to as *cladding* processes. (S. 31.)

Composite Compact. A metal powder compact consisting of two or more adhering layers of different metals or alloys, with each layer retaining its original identity. (G. 30.)

Composite Electrode. A filler-metal electrode, used in arc welding, consisting of more than one metal component combined mechanically. It may or may not include materials which protect the molten metal from the atmosphere, improve the properties of the weld metal or stabilize the arc. (A. 37.)

Composite Forgings. Compound units fashioned out of separate elements and comprising a cutting face of tool steel, integrated with a wide mild steel base. The tool steel cutting face very closely approximates to the required contours of the finished die in both elevation and plan. Therefore, a set of these forgings assemble, like a jig-saw, into a complete die with a minimum amount of machining. (M. 83.)

Composite Joint. (See JOINTS.)

Composite Metal. Metallic material in which two distinct metals are combined, e.g. as in *Bundyweld* or *Copperweld*. (See also CLADDING.)

Composite Structure. A composition consisting of a physical mixture of two or more metals, or one or more metals with one or more non-metals, all in finely divided form, whose inability to form alloys or compounds results in retention of the properties of the individual components. (G. 30.)

Composite Tube. A tube produced from two tubes of different materials. One is placed inside the other and the two are then *cold drawn* or hot reduced together.

Composition Vertical. A vertical line drawn in a *constitutional diagram* to indicate an alloy of definite composition.

Compound. (See CHEMICAL COMPOUND.)

Compound Lock. (See LOCK.)

Compressibility. The ability of a mass of powder to yield to pressure.

Compression. A direct push against the axis of a body and, therefore, the opposite of *tension*.

Compression Creep Test. A test developed to indicate at an early stage of research which alloys show most promise. The apparatus, which was developed from an N.P.L. prototype, uses a simple ground cylindrical compression specimen with a gauge length of 0·25 in., diam. 0·125 in., with cylindrical shoulders 0·125 in. long and 0·25 in. diam. The specimen is surrounded by a furnace maintained at the correct temperature and compressed between two push-rods of commercially recrystallized alumina, which does not creep significantly at 1000° C. and under a stress corresponding to 10 tons per sq. in. in the specimen. Loading is accomplished by means of a beam, whose deflection measures the strain. The apparatus can be used at creep rates, down to 2×10^{-6} strain per hour. (S. 155.)

Compression Forming. (See ROTARY FORMING and ROCKRITE PROCESS.)

Compression Ratio. The ratio of the volume of the loose powder to the volume of the compact made from it by the application of a specific pressure in a specific *die* at a specific pressing speed.

Compression Test. This consists in imposing a dead load on a small cylindrical test piece of which the diameter is usually equal to half the length. The compressive strength is expressed in tons per sq. in. In general, the test is used in this country for the determination of the properties of cast iron, but the American Society for Testing Materials have suggested certain modified dimensions for compression test specimens to meet specific requirements, as, for example, the testing of bearing metals.

Compressive Elastic Limit. The maximum compressive stress to which a material may be subjected without permanent deformation or set. The value is expressed in tons per sq. in.

Compressive Strength. (*a*) The maximum compressive stress to which a material may be submitted without failure. It is expressed in tons per sq. in. In cast iron, compressive stress is next in importance to tensile strength since in many structural castings the material is used in the state of compression rather than in any other form of stress loading. The compressive strength of cast iron does not bear any direct relationship to the tensile strength but, it may be taken as approximately three to four times the maximum tensile stress, the ratio decreasing as the quality of the iron increases. (*b*) In sand, the *maximum stress* in compression which a sand mixture is capable of developing.

Compressive Yield Point. The stress in compression at which marked deformation occurs without failure. It is expressed in tons per sq. in.

Compressive Yield Strength. The maximum stress that a metal subjected to compression can withstand without undergoing a predetermined amount of deformation. It is expressed in tons per sq. in.

Concentrated. Containing the minimum of water or other solute.

Concentration. (*a*) The number of molecules or ions present in a given volume, i.e. the concentration of aqueous solutions is generally given in grams per litre. (*b*) The process of increasing the metal content of an ore by elimination of the *gangue*.

Concentration Cell. An electrolytic cell, the e.m.f. of which is due to a difference in concentration of the electrolyte or active metal at the *anode* and the *cathode*.

Concentration Polarization. That portion of the polarization of a cell produced by concentration changes resulting from passage of current through the electrolyte.

Concentric Converter. A modification of the Bessemer converter in which the mouth is at the centre of the top.

Conchoidal Fracture. (See FRACTURE.)

Concrete. A constructional material consisting essentially of a mixture of cement, gravel and broken brick or stones, in varying proportions. *Reinforced concrete* is concrete which contains an internal steel structure, often in the form of steel rods for the purpose of conferring additional strength.

Condenser Tubes. Tubes used in the conversion of a vapour into the liquid state by cooling.

Conditioning. The removal of surface defects, such as *seams* or *laps*, by chipping or grinding. The process is usually carried out on semi-finished steel, e.g. blooms, billets and slabs.

Conductance, Thermal. (*C.*) The time rate of heat flow through unit area of a body, of given size and shape, per unit temperature difference. Common unit is: *B.Th.U.* per (hour) (square foot) (Fahrenheit degree).

Conduction, Thermal. The process of heat transfer through a material medium in which heat is transmitted from particle to particle without gross displacement of the particles

Conductivity, Electrical. (See ELECTRICAL CONDUCTIVITY.)

Conductivity, Thermal. (*Heat Conductivity.*) Rate of transfer of heat along a body by conduction. Measured in calories flowing per second across a centimetre cube of the substance having a temperature difference of 1° C. on opposite faces, or similarly for other units of measurement.

Conductometric Analysis. A method of determining small amounts of carbon in steels by measuring the change in conductivity of a barium hydroxide solution on absorption of carbon dioxide. (B. 42.)

Conductor, Thermal. A material which readily transmits heat by means of conduction.

Cone. (*a*) The luminous inner part of a flame which lies next to the orifice of the blowpipe nozzle. (*b*) (See PYROMETRIC CONE EQUIVALENT.)

Cone Arc Welding Process. A method developed for the welding of miniature heat exchangers of the tube to header type of design. The basic principle of the process is the rotation of the arc round the header hole at high speeds, giving uniform distribution of the energy required to make a peripheral weld of a tube into a header sheet. (P. 13.)

Cone Mill. A mill for the production of seamless steel tubes, which uses conical rolls set at an angle of 60°.

Cone Test. A test developed for evaluating the hardenability of steels with *Shepherd P-F numbers* of 10 to 16. The test consists of hardening a conical specimen, 5 in. long and having a ½ in. diam. at the small end and a 1½ in. diam. at the large end, by quenching from a furnace, containing a controlled atmosphere into a 3-in. spray of 10% brine solution, with the apex down. After hardening, the cone is split longitudinally through the centre, and *Rockwell C hardness* is determined on the longitudinal axis. The cooling rate contour of the cone specimen during brine quenching from 790° to 900° C. is determined, and, with the point of critical hardness (Rockwell C hardness 55 for *hypereutectoid* steels) fixed by a hardness traverse of the axis of the cone, it is possible to determine the cooling rate necessary to obtain that hardness. (P. 38.)

Congener. One of the same kind, e.g. a member of the same group in the *periodic system.*

Conimeter. An instrument for the gauging and measurement of hole cones. The measuring element of the conimeter is a dial gauge, each division of which corresponds to one thousandth of an inch. Two adjustable pointers are provided which allow the maximum and minimum limits of tolerance to be set on the dial, so that it is immediately evident whether a cone is being measured satisfactorily. (I. 16.)

Conjugate Solutions. Two solutions existing together in equilibrium at a given temperature in such a condition that any variation in the temperature results in a change of the relative proportions of the solutions and of their compositions.

Conjugated System. A chemical system characterized by a transmission of chemical reactivity from one atom to another.

Connor Runner. (*Lip Feeder.*) A form of runner in which the feed block overlaps the casting by $\frac{1}{16}$ in. The downgate is gated to the feeder block so that all metal, entering the mould cavity, passes through the narrow feedgate and intensely heats the surrounding sand. (F. 4.)

Conode. (*Tie Line.*) The anglicized version of *Konode* which is a German term for a line connecting two phases which are in equilibrium with each other.

Conservation of Matter, Law of. The law which states that in every chemical process the quantity of matter remains constant and only the form changes, i.e. the total mass taking part in a chemical reaction is equal to the mass of the resulting products.

Consistency. That property of a body by virtue of which it tends to resist deformation. (A. 28.)

Consolute. Mutually soluble in all proportions.

Consolute Temperature. (See CRITICAL SOLUTION TEMPERATURE.)

Constant Pressure Lathe Test. A method of ascertaining the probable performance of bar stock in commercial machining operations with a reasonable degree of repetitive accuracy. A Monarch lathe is equipped to provide a constant feed force in the horizontal direction by means of a system of pulleys and weights attached to the saddle. The amount of metal removed is found by measuring the spindle speed and the time taken for the saddle to move a certain distance. (S. 34.)

Constantan. An alloy consisting of about 55% copper and 45% nickel. (See IRON-CONSTANTAN COUPLE.)

Constituent. A phase visible under the microscope.

Constitution. The chemical form and microstructure of the constituents of an alloy.

Constitutional Change. A change affecting the nature or proportions of the constituents of an alloy.

Constitutional Diagram. (See PHASE DIAGRAM.)

Consultants' Bureau. 153 West 33rd St., New York 1, N.Y. The Consultants' Bureau translates German documents which have been recommended by the Film Study Group of the American Petroleum Institute. In addition, it publishes translations of certain reports which have been produced by the *Office of Technical Services.*

Consumable Electrode. A metal electrode which provides filler metal.

Consumed Weight. In forging, the weight of the original metal used divided by the number of forgings accepted by the customer. All material lost in production including rejected forgings is included.

Contact Angle. In rolling, the angle formed between the line of the centres of the rolls and a radius to the top of the rolled pieces. The arc equivalent to this angle is termed the *contact arc.*

Contact Arc. (See CONTACT ANGLE.)

Contact Arc Welding. The process derives its name from the fact that the electrode is kept in contact with the work at all times which eliminates the need of maintaining a specified length of arc. The success of contact arc welding is attained through extremely heavy coatings on the contact elec-

trodes. These coatings serve two functions, namely, in preventing the heavy coatings from depositing undue amounts of *slag* in proportion to metal deposited, and by providing sufficient electrical conductivity in the coating to establish an arc. It is not necessary to strike an arc, because of the self-starting action. Likewise, the action of the coatings is automatic in re-starting after interruption in welding. (D. 51.) (Y. 5.)

Contact Area. (*a*) The surface of contact between the parts when pressure is applied during a *pressure-welding process*. (*b*) The area of a rolled piece under the *contact arc*.

Contact Automatic Welder. This consists of a welding head fitted with an oblique bar sliding in its own longitudinal direction and with the welding electrode clamped to its lower end at a given angle. The weight of the bar presses the tip of the electrode on to the workpiece and as the electrode melts down it is carried along parallel to itself. The rate of travel, and thus the thickness of the weld, is adjusted by varying the angles at which the bar and the electrode are set. (B. 64.)

Contact Bar. A conductor that in a *resistance-welding* machine conveys current to, and exerts mechanical pressure on, the parts to be welded.

Contact Corrosion. The corrosion occurring when two dissimilar metals are in contact in the presence of a liquid which can serve as an electrolyte. Owing to the different solution pressures of the two metals, electric potentials similar to those operating in an ordinary voltaic cell are set up and the less *noble* of the metals is liable to be attacked. (See ELECTROCHEMICAL SERIES.)

Contact Electrodes. Electrodes in which a large amount of iron powder is incorporated in the coating, thus making it a semi-conductor. Thus, striking the arc with contact electrodes is extremely easy and because the coating is always in electrical, as well as mechanical, contact with the workpiece, the name *contact arc welding* was given. (W. 58.)

Contact Jaw. A clamping device that in a *resistance-welding* machine secures the parts to be welded and conducts the current thereto.

Contact Point. The part of an electric conductor that in a *resistance-welding* machine conveys current to and exerts mechanical pressure on the parts to be welded.

Contact Point Insert. A metal tip inserted in a *contact point* to increase its durability.

Contact Printing. (*Ink Print.*) A method of recording details of a macro-etched structure. A thin coating of black printers' ink is evenly distributed over the etched surface. A sheet of thick white paper is then pressed on the inked surface, and the details of the surface are thus imprinted on the paper.

Contact Roller. A rotating part employed in *resistance-welding* to convey current to and exert pressure on the parts to be welded.

Contact Thermometer. A mercury-filled thermometer having two contacts fused through the glass, such that a connection is made through the expansion of the mercury. In some forms, the position of one contact is adjustable by means of an external magnet so as to vary the control set point. (C. 22.)

Contact Welding. (See CONTACT ARC WELDING.)

Continuous Annealing Furnace. A furnace in which castings are annealed by passing through different zones which are kept at constant temperatures. (A. 26.)

Continuous Billet Mill. A rolling mill in which the steel is rolled down from an ingot to a billet by a series of horizontal roll stands placed in tandem.

Continuous Casting. A casting technique in which the ingot is continuously solidified while it is being poured, and the length is not determined by mould dimensions. The various processes are described under their respective headings.

Continuous Current. (See DIRECT CURRENT.)

Continuous Drawing. The production of wire by drawing through a series of dies without intermediate handling or treatment.

Continuous Electrode. A type of electrode used in an *electric arc furnace*; it is replenished as it is consumed (e.g. *Soderberg Electrode*).

Continuous-Feed Weld. A weld in which a *filler rod* is used and fed continuously by mechanical means, the rate of feed being under the control of the operator.

Continuous Furnace. A type of reheating furnace in which the contents are charged at one end and move continuously through the furnace by mechanical means until they are discharged at the other end.

Continuous Gas Carburizing. A process which consists essentially of entering work at one end of a furnace and discharging it at the other end in a carburized condition. A mixture of natural hydrocarbon gas with a reducing flue gas as diluent, is used, the carbon deposited on the work in the heating zone of the muffle combining with the carbon dioxide in the flue gas to give

free carbon monoxide which is an active carburizing agent. (C. 54.)

Continuous Metalcast Process. A method of continuous casting in which metals or alloys are intermittently fed from the regular plant melting furnaces into one end of a holding furnace and bottom poured from the other end into a water-cooled mould, which is oscillated to increase cooling efficiency. A pair of pinch rolls withdraw the solidified casting, below which the bar is cut into convenient sizes by means of a flying saw in the case of non-ferrous metals, or by a torch in the case of steel castings. (See JUNGHANS-ROSSI PROCESS.) (R. 44.)

Continuous Mill. (See ROLLING MILL.)

Continuous Phase. In alloys containing more than one phase, that phase which forms the matrix or background in which the other phase or phases are present as isolated units. (A. 26.)

Continuous Sequence. A weld in which each pass is made continuously from one end of the joint to the other. (See BACKSTEP SEQUENCE, LONGITUDINAL SEQUENCE.) (A. 37.)

Continuous Weld. A weld extending along the entire length of the joint. All welds are considered to be continuous unless otherwise specified. (B. 105.)

Continuous Weld Process. (See FRETZ MOON PROCESS.)

Contorograph. An instrument for the recording of surface finish, the relative vertical motion between the surface and a traversing gramophone needle being magnified and recorded optically. (S. 46.)

Contraction. The shrinkage occurring in metals (with the exception of *antimony*) and alloys on cooling.

Contraction Cavities. Voids formed when the supply of molten metal fails at certain points. In castings, the bulk of the contraction that accompanies the solidification is concentrated in the *feeder heads* and *risers*, from which molten metal flows to compensate for contraction in the casting or ingot proper, whilst in steel ingots the contraction results in the formation of pipe.

Contraction Crack. A crack formed by the metal pulling itself apart while cooling in the mould or a short time after its removal from the mould. The walls of such cracks are often discoloured according to the temperature of the casting when failure occurs. The defect is termed *hot tear* when fracture takes place around or just after solidification of the metal. This defect has an external appearance very similar to a liquid shrinkage crack but can always be differentiated from the latter by the fact that there is no cavity or porous area beneath. (I. 14.)

Contraction Rule. A rule divided in excess of standard measurements used by *patternmakers*, and thus avoiding calculations for shrinkage. (A. 26.)

Contractometer. An instrument for the measurement of stress in electrodeposits. It consists of a flat metal strip wound in the form of a helix and connected to a pointer moving over a dial to show the rotation of the free end of the spiral. A single helix can be used almost indefinitely without appreciable change in its dimensions, elastic moduli, or deflection constants. (I. 7.)

Contrast Etching. Etching with the object of producing different depths of attack, thus revealing distinctions in colour in the different grains. It is used as a means of determining grain size.

Contrast Factor. In *spectrographic analysis*, the contrast factor is obtained from the rate of change of photographic density with respect to the common logarithm of exposure and is the slope of the characteristic curve at any particular density.

Controlled Arc Welding. Metal-arc welding in which the rate of feed of the electrode is controlled by the arc voltage (M. 110.)

Controlled Atmosphere. Any gas or mixture of gases which prevents or retards the processes of surface oxidation and decarburization of steel parts during heat treatment.

Controlled Cooling. A process by which a steel object is cooled from an elevated temperature, usually from the final hot-forming operation, in a predetermined manner of cooling to avoid hardening, cracking or internal damage, or to produce a desired microstructure.

Controlled Density Steels. Such steels may be produced with carbon contents ranging from less than 0·01% up to 1·5%. Alloying additions can also be made to the ore and a wide variety of alloys have already been produced by this method. If the final form of the steel is to be rods, bars or wire, the iron ore is poured into a paper tube or some type of porous mould such as a *Croning* sand mould or porous graphite mould. The tubes, full of ore, are placed in a metal or ceramic *sagger* which is then filled with a mixture of coke breeze and limestone and sealed. The loaded container is then heated to 1095° C. and held for sufficient time to produce the desired carbon content and density. The density of the finished article will depend upon the swelling or shrinking characteristics of the iron ore employed,

on the maximum particle size, and on the particle size distribution. For hot working, the density of the steel coming from the furnace must be more than 3·0 and is preferably over 4·0. (E. 30.)

Controlled Thermal Severity Weldability Test. (*C.T.S. Weldability Test.*) The test comprises a series of restrained fillet welds, using the steel and electrode under consideration. Each test assembly incorporates two test welds of equal size, one of which may be considered to have a thermal severity equivalent to that of a butt-weld in the material under test, and the other a thermal severity equivalent to that of a normal fillet weld in the same material. This difference in severity is due to the geometry of the assembly. An examination of the test weld is made to determine whether cracking has occurred in either the weld metal or the heat-affected zone of the parent plate. (B. 79.)

Convective Heat Transfer. The transmission of heat by either natural or forced motion of a fluid (liquid or gas).

Converted Bar. (See CEMENTATION.)

Converter. A vessel in which air is blown through the molten bath of pig iron for the purpose of oxidizing impurities. (See BESSEMER PROCESS.)

Converting Furnace. (See CEMENTATION.)

Converting Pots. (See CEMENTATION.)

Converting Process. (See CEMENTATION.)

Convex Fillet Weld. A *fillet weld* in which the exposed surface lies outside a straight line joining the toes.

Cooke Micro-Hardness Tester. In this instrument a *Vickers diamond* whose faces have been worked to an angle of 136° is embedded in the outer optical surface of the microscope objective, thus the area to be tested can be selected and the indent made and evaluated without the interchange and exact registration of indenter and objective. The load applied may vary from 0·1 to 500 g. and a set of weights as supplied with a chemical balance will serve. The specimen is secured to one end of an accurately balanced lever and the selected weight is applied to a platform immediately above the specimen. The combined objective and diamond indenter are advanced towards the specimen by means of the slow motion focusing adjustment of the microscope and contact is indicated by a signal lamp. The measurement of the impression is made with the aid of a ruled graticule fixed in the focal plane of the microscope eyepiece.

Cookie. A finished section of armour plate.

Cool Time. The period of time between the successive application of current impulses in *pulsation welding*.

Coolants. (See CUTTING FLUIDS.)

Cooler. (See CINDER NOTCH.)

Cooler Plated Steel. *Rimming steel* in which reaction in the ingot mould has been arrested by inserting a plate on the top of the mould, after *teeming*. (See also CAPPED STEEL.)

Coolidge Tube. A type of X-ray tube that has a high vacuum and a hot wire cathode. (A. 27.)

Cooling Bed. A large steel rack, usually situated at the finishing end of a rolling mill, on which the finished bars are placed and allowed to cool.

Cooling and Heating Curves. (*Time-Temperature Curves.*) Graphs showing the rate of cooling or heating of a body. They are obtained by plotting time against temperature for a metal cooling or heating under constant conditions, and indicate the *transformation ranges* by virtue of the fact that the phase changes are accompanied by heat absorption or generation.

Cooling Floor. The space between the roll stand and the cutting shears, in a *rolling mill.*

Cooling Stresses. Stresses developed by uneven contraction or external constraint of metal during cooling; also those stresses resulting from localized plastic deformation during cooling, and retained. (A. 27.)

Cooling Zone. That part of a *continuous furnace* in which the parts under treatment cool after passing through the heating zone.

Co-ordination Lattice. A crystal lattice in which each ion bears the same relation to its neighbouring ions.

Cope. (*Case.*) The upper half of a *flask, mould* or *pattern.* (See FLASK.)

Cope Down. The operation of building projecting bodies of sand on the surface of the *cope* to form surfaces of the *casting* which are below the level of the joint of the *drag.* (P. 1.)

Cope Plate. An iron plate used to support certain portions of *loam moulds.* (P. 1.)

Coping Out. The extension of the sand of the *cope* downward into the *drag,* where it takes an impression of a *pattern.* (A. 26.)

Copper. (*Cu.*) *Atomic weight* 63·54. *Specific gravity* 8·96. *Melting point* 1083° C. Copper is ductile, with high electrical and thermal conductivity, and good resistance to corrosion; it has many uses, notably as an electrical conductor. It is the basis of brass, bronze, aluminium bronze and other alloys. The addition of about 0·2% copper to low carbon steel may increase its resistance to atmospheric corrosion

by as much as 20% to 30%. In amounts of about 0·5%, copper appreciably increases the tensile and yield strengths. The addition of increasing amounts of copper leads to defects in rolling. High yield point structural steels containing copper in association with chromium and appreciable percentages of silicon and phosphorus have been developed. (See also CYPRITIC STEEL.)

Copper Bit. A *soldering iron.*

Copper-Constantan Couple. A thermocouple consisting of a positive wire of copper and a negative wire of *constantan.* It is recommended for use in reducing or mildly oxidizing atmospheres at temperatures up to about 350° C.

Copper Core Process. A process for making hollow steel drills in which a hole is made down the centre of the billet, and a rod of copper inserted therein. The billet is then heated, rolled, and allowed to cool, after which the rod is removed, leaving a hole through the entire length of the bar.

Copper Plated Steel. Sheet produced by placing a copper sheet on a steel billet and pressing the two together by passing them between rolls in a protective atmosphere at a temperature of about 950° C. The object of the copper plating is to protect the steel from corrosion. (T. 11.)

Copper Steel. (See COPPER.)

Copper Sulphate Dipping Test. A method of examining the zinc coating of galvanized wire in which it is required that a galvanized sample after a specified number of dips of specified duration in a solution containing 30 g. of crystalline copper sulphate in each 100 ml. of water, at a temperature of 60° F., shall show no adherent deposit of metallic copper upon the base metal after final rinsing and drying. (B. 104.)

Copperas. (See IRON VITRIOL.)

Coppered Wire. This is produced by wet drawing wire with a copper sulphate or copper-tin sulphate solution. The colour varies in accordance with the chemicals used. The drawing operation imparts a lustre to the wire, resulting in improved appearance and a limited amount of corrosion resistance. (T. 33.)

Copperweld. Steel wire having a copper armour which approximates 10% of the diameter. It is made by casting molten copper around a steel billet, hot rolling the compound billet and drawing into wire. (T. 33.)

Coppite. A niobium-containing mineral used as raw material in the production of *ferro-niobium.*

Cor Fatigue Machine. An alternate plane bending machine for testing metal strips with unmachined surfaces. One end of the strip is gripped whilst the free end is vibrated at a rate of 6000 cycles per minute by means of an alternating current electromagnet. Strip up to 10 mm. gauge may be tested in this machine.

Cordierite. A special blend of talc, alumina and clay, which is noted for its low expansion characteristics. It has been used for foundry moulds.

Core. (*a*) A shape, made in *core sand* and baked hard in a *core oven,* which is inserted into the mould before casting to form an internal cavity of some part of the casting which cannot be shaped by a pattern. After the casting has cooled, the core is broken up and removed. (*b*) The inner and non-carburized portion of a *case-hardened* steel which is always considerably softer than the surface layer or case; (*c*) The inner portion of rolled *rimming* steel; (*d*) That part of a magnetic circuit around which the winding is placed; (*e*) Sometimes used to designate the relatively soft central portion of certain hardened *tool steels;* (*f*) The base portion of a *clad* product; (*g*) A tubular defect that comes from the surface of a billet and appears at the back end of an extruded product; (*h*) (See CORE DRAWING.)

Core Bar. An iron bar used in the foundry for the production of loam *cores.* Loam mixed with the required bond is put on the bar which is then rotated, the desired external shape being obtained by means of a shaped *loam board* which is pressed against the surface of the core as it rotates.

Core Barrel. A skeleton former on which large round *cores* are built.

Core Blower. A *blowing machine* consisting normally of three essential components: (1) blowing head; (2) air diaphragm to the blowing head; (3) sand and air outlet to the *core box* usually known as the *blowing plate.* The primary object of the blower is to fill and ram sand into the core box as quickly as possible, expelling to the atmosphere all air, thus ensuring an evenly rammed core. (F. 9.)

Core Blowing. A method of making cores by blowing the sand into the *core box* by means of compressed air.

Core Bonds. (See CORE COMPOUNDS.)

Core Box. A wooden box in which the core is formed preparatory to *sand casting,* the cavity in the box having the shape of the core which is to be made therein.

Core Breaker. A machine for crushing *cores* or for removing cores from castings. (A. 26.)

Core Cavity. The interior form of a core box which gives shape to the *core.* (A. 26.)

Core Compounds. (*Core Bonds.*) Commercial mixtures used to supply the binding material needed in making cores. They consist principally of core oils, core creams and semi-solid compounds containing dextrin and linseed oil as the most important constituents, with selected proportions of molasses, sulphite lye, resin or other binders, and some water. Dextrin gives high green strength and fairly high dry strength, whilst linseed oil gives very little green strength but very high dry strength so that, by altering the proportions of these, core compounds may be made with different properties as desired. (M. 170.)

Core Crab. An iron framework embedded in a large *core* to stiffen it, and for convenience in handling. (P. 9.)

Core Drawing. A method used in the production of small diameter and in particular, of thick wall or multibore tubes, e.g. capillary tubing. The process superficially resembles *mandrel drawing* in that an internal supporting member is employed which passes through the die with the work, but in core drawing, the core is in the form of a wire which can be reduced and elongated with the work. The usual procedure is to insert a hard-drawn core wire in the bore of the annealed work which thus gives the necessary support during drawing. The core can be annealed with the work and remain in position throughout a sequence of drawing operations or be replaced prior to each draw. (M. 50a.)

Core Driers. Sand or metal supports used to keep *cores* in shape while being baked. (A. 26.)

Core Frame. A frame of skeleton construction used in forming intermediate and large cores. (A. 26.)

Core Grid. A skeleton framework upon which the larger cores are formed.

Core Irons. Bars of iron embedded in a *core* to strengthen it. Larger and more complicated cores are provided with bent iron rods or grids cast specially to suit the shape of the work.

Core Knockout Machine. A mechanical device for removing *cores* from *castings.* (A. 26.)

Core Lamination Insulation. A coating applied to electrical sheets for the purpose of increasing the interlamination resistance. Sometimes called *Core Plate Enamel.* (A. 28.)

Core Loss. (*Watt Loss.*) The energy expended in magnetizing a material with an alternating electric current. Core loss is made up of two components, *hysteresis* and *eddy current losses.*

Core Marker. A core seat so shaped or arranged that the core will register correctly in the mould. (A. 26.)

Core Oil. Linseed-base or other oil used as a core binder. (A. 26.)

Core Ovens. (See CORE STOVES.)

Core Paste. A prepared adhesive for joining sections of cores. (A. 26.)

Core Plate Enamel. (See CORE LAMINATION INSULATION.)

Core Plates. Cast iron or mild steel plates on to which the green cores are turned out and transported to the drying ovens and which are used to support them during baking.

Core Plating. Coating silicon steel transformer sheets with varnish.

Core Prints. (*Registers.*) (*a*) Recesses or seating formed in a *mould* in which the ends of *cores* are *set.* (*b*) The projections on a *pattern* which form and locate the prints in the mould.

Core Raise. A *casting* defect caused by the core moving towards the *cope* surface of a mould, resulting in a variation in wall thickness. (A. 26.)

Core Rod. In powder metallurgy, a member of a die used in producing a hole in a *compact.*

Core Sand. *Silica sand* to which a binding material has been added in order to obtain good cohesion and porosity after drying for the purpose of making *cores.*

Core Shift. A variation from specified dimensions of a cored section, due to the change in position of the core or mis-alignment of the core assembly. (A. 26.)

Core Stoves. (*Core Ovens.*) Specially heated chambers for the drying of cores at low temperature.

Core Vents. Holes made in the core to allow the gases, formed during casting, to escape.

Cored Bar. In powder metallurgy, a *compact* of bar shape heated by its own electrical resistance to a temperature high enough to melt its interior.

Cored Electrode. (See ELECTRODE.)

Cored Structure. (See DENDRITE.)

Coreless Induction Furnace. (See HIGH FREQUENCY FURNACE.)

Coremaker. A craftsman skilled in the production of *cores* for *foundry* use. (A. 26.)

Coring. (See DENDRITIC SEGREGATION.)

Cornelius Electronic Comparator. An instrument which produces impulses of a definite value at a basic frequency. These impulses are imparted to a detector or adapter, where they are modulated in frequency by the subject under test. The modulated frequency is passed back to an oscillator valve which con-

verts the frequency variations into current variations, whence the voltage is amplified to a degree permitting a selective circuit to play its part. The comparator is used in conjunction with a tensile testing machine in material analysis. The plotting of metre deflection against strain gives a very characteristic graph, which can be regarded as the "signature" of the material under test. (A. 16.)

Corner Ghost. (See GHOST.)

Corner Joint. In welding, a joint where the parts joined form approximately a right angle with one another, and an edge or end of one part is situated at or near a surface of the other part but does not intersect it. (B. 105.)

Corona. The area sometimes surrounding the nugget of a spot weld at the faying surfaces, which provides a degree of bonding. (A. 37.)

Corronizing Process. A rust-proofing process, in which nickel is first deposited on steel, and zinc or tin over the nickel, the material being finally heated to 260° to 400° C. for up to six hours, to obtain diffusion, the exact conditions depending on the thickness of the base metal and the requirements of the finished material. The protective effect depends on the fact that a series of alloy layers of progressively changing composition is formed, each layer being sacrificial to the one below it. The main application of corronizing is for protection against sulphurous attack. (W. 64.)

Corrosion. The destruction of metal or alloys by chemical or *electrochemical* agencies, as in the rusting of iron. The rate of the reaction increases with humidity and the presence of favourable elements or components, as, for example, *sulphur* in industrial atmospheres, salt spray in marine atmospheres, and acids in chemical plant. The action of oxygen varies in different conditions. The direct oxidation of iron leads to the formation of scale which may suppress further corrosive action. Limited supplies of oxygen favour corrosion by an electrochemical mechanism. Important corrosion currents flow when two dissimilar metals are placed in contact in a liquid. The current strength increases if oxygen is supplied to the cathodic metal. Oxide scale on steel also acts as a cathode towards the steel exposed in small cracks and leads to severe pitting. When cathodic metals, such as copper or nickel are used for the coating of steel, corrosion is likely to occur if there is discontinuity of the layer. Porosity can be reduced by ensuring a satisfactory surface of the basis metal. A low sulphur content of steel reduces the danger of attack through the pores. Better protection is afforded by coating steel with anodic metals, such as zinc, or aluminium. The cathodic reaction deposits a protective layer on the exposed surfaces of steel and the action slows down. (See also OXIDATION.) (E. 88.)

Corrosion Cracking. (See SEASON CRACKING.)

Corrosion Embrittlement. The embrittlement caused in certain alloys by exposure to a corrosive environment. Such material is usually susceptible to *intercrystalline corrosion*. (A. 27.)

Corrosion-Fatigue. Corrosion combined with alternating stress which accelerates the fatigue. The severity of the action depends upon the range and frequency of the stress, the intensity of the corroding conditions, and the time. The fracture is of a brittle type, akin to a fatigue fracture, but exhibiting a characteristic discolouration, dark at the nucleus and grading away to a lighter shade with increasing distance from it. Tests on the corrosion-fatigue of metals are usually carried out in a similar manner to those for fatigue with the addition of a means for applying the corrosive agent to the test pieces. A number of factors affect corrosion-fatigue. The attack has been shown to align itself with existing slip-planes. Although different metals have different resistance to attack, changes of composition of specific alloys have proved surprisingly unimportant, except where they tend to confer special resistance to chemical corrosion. The nature and concentration of the corrosive solution follow very closely the actions they would have in chemical corrosion and the severity of the attack increases with the increase of temperature. (G. 38.)

Corrosion Index. A number expressing the maximum depth in *mils* to which corrosion would penetrate in one year on the basis of a linear extrapolation of the penetration occurring during the lifetime of a given test or service. (Z. 4.)

Corrosion-Resisting Steels. (See STAINLESS STEELS.)

Corrosive Sublimate. A highly volatile and extremely poisonous chloride of mercury.

Corrosivity Measurement. One device developed for measuring the corrosivity of water and condensates in steam heating systems consists of three helical coils of Bessemer steel wire, 0·05 in. diam., mounted on a frame which can be inserted in the pipes of the system. After about 28 days' exposure, the frame is taken out, the

products of corrosion are removed, by an acetic acid solution containing an inhibitor, and the loss in weight is determined. The three coils are of the same dimensions and the average loss in weight is taken as an indication of the corrosiveness of the condensate. (W. 4.)

Corrugated Sheets. Plain carbon or copper steel sheets uniformly crimped or corrugated for the length of the sheet and supplied with either a black or galvanized finish. The corrugations give the sheets structural strength and load-carrying ability. They are used for roofing, etc.

Carson's Reagent. An etching solution containing 2 parts hydrofluoric acid, 1 part nitric acid and 2 parts glycerol.

Cort, Henry. (1740–1800.) Introduced the use of grooved rolls in rolling mills in 1783, and in 1784 invented the dry *puddling process* in which coal was used instead of charcoal. (N. 4.)

Corubin. A crystalline substance formed on cooling fused alumina.

Corundum. A mineral (Al_2O_3) having a hardness of 9 on *Mohs' Scale*, used as an abrasive.

Corvusite. ($V_2O_4.6V_2O_5.H_2O$.) A vanadium ore.

Coslettizing. The process of producing a black rust-resisting surface on iron and steel articles by boiling for some hours in water containing 4 oz. of phosphoric acid and 1 oz. of iron filings per gallon.

Cottrell Process. A method of cleaning blast furnace gas which depends on the principle that if a body highly charged with electricity is brought near to a particle able to move freely in any direction, the latter will receive a charge of the same sign as that of the charged body and will be violently repelled from it. This is what takes place in an electrical precipitator, except that the charged body is fixed and the particles are brought to it. In its simplest form, the precipitator consists of two sets of electrodes, i.e. the discharge electrodes, and the collecting electrodes. The gases carrying the suspended particles to be removed are passed between the discharge and collecting electrodes, the particles become charged and are driven away from the discharge electrodes and across to the collecting ones, upon which they are deposited. The gases are unaffected and pass on out of the precipitator chamber. The method is being adopted also in connection with sintering installations, the gases from which contain free sulphuric acid and sometimes elemental sulphur. (E. 6.)

Coulomb. A unit of electricity comprising the amount which passes a cross-section of the conductor in 1 second when the rate of flow is 1 amp.

Coulomb Field. Field produced by a charge acting as if concentrated at a point so that the field intensity varies inversely with the square of the radial distance from that point.

Coulomb Law. (*Force Between Two Charges.*) A fundamental law which states that the electrostatic attraction or repulsion between two charged bodies is proportional to the magnitudes of their charges and inversely proportional to the square of the distance between them.

Coulometer. An electrolytic cell arranged for the measurement of the quantity of electricity passing, by the accurate measurement of one or more of the products of electrolysis.

Counter Lock. (See LOCK.)

Countersink. In a twist drill, the tapered and relieved cutting portion situated between the pilot drill and the body.

Counting Strain Gauge. The instrument consists of a dumb-bell-shaped piston, sliding in a cylinder, and carrying a number of pairs of spring-loaded plunger contacts projecting outside the two piston heads. End blocks of insulating material are attached to each end of the cylinder and are fitted with adjustable screw contacts corresponding with the plunger contacts in the piston. In operation, the cylinder is attached to one side of the structure and the piston to the other. Under strain, the piston moves inside the cylinder and one or more plungers touch the contacts and register a count in an electro-magnetic counter. (L. 2.)

Couple. Two dissimilar conductors in electrical contact. An *electromotive force* is created under proper electrolytic influences or during heating. (A. 27.)

Couple Action. (See GALVANIC CORROSION.)

Coupler. The socket in a screwed and socketed joint.

Coupler Tubes. Tubes of suitable dimensions for the production of *couplers*.

Coupling Box. A loose-fitting connection between the roll and the spindle in a rolling mill.

Coupons. (See TEST BLOCK.)

C.O.V. Concentrated *oil of vitriol*.

Covelline. (See COVELLITE.)

Covellite. (*Blue Copper, Indigo Copper, Covelline.*) Native cupric sulphide commonly found in Chile.

Cover Core. A core set in place during the ramming of a *mould* to cover and complete a cavity partly formed by the withdrawal of a loose part of the *pattern*.

Cover Sheet. A protective metal sheet laid over a steel sheet during heat treatment in a continuous type furnace.
Cover Straps. As applied to welds, narrow strips of plate welded across butt-welded seams at intervals along the length of the seam.
Covered Electrode. A welding *electrode* consisting of metal rod with a flux covering, applied by painting, spraying, dipping, wrapping, or other method.
Covering Power. The extent to which the cathode is covered by the electro-deposited metal.
Cowper Coles. (See SHERARDIZING.)
Cowper's Stove. A type of *hot blast stove* patented by E. A. Cowper about the middle of the 19th century. It was used to preheat the blast for the blast furnace.
C.P. (*a*) Abbreviation for candlepower. (*b*) Chemically pure.
"C" Process. (See CRONING PROCESS.)
C.P.S. Cycles per second.
C.R. Abbreviation for *cold rolled.*
Cr. Chemical symbol for *chromium.*
Crab. (See CORE CRAB.)
Cracked Ammonia. A gaseous mixture consisting of one part of nitrogen with three parts of hydrogen derived by splitting up the molecular ammonia (NH_3) into its constituent elements by passing it over a catalyst at a suitable temperature.
Cracked Back. (See BROKEN BACK.)
Cracked Edges. (*Checked Edges.*) (*Raw Edges.*) Transverse cracks on the edges of sheet or strip.
Crackless Plasticity. The property which appears to permit submicroscopic yielding at the region of stress without the formation of a crack. (See also DAMPING.)
Cracks. A general term for fissures or ruptures which may occur at all stages of production up to the finished product.
Cramp Bars. (*Guide or Rest Bars.*) Bars which are fixed horizontally on each side of the mill and parallel to the rolling plane, the ends being firmly secured in slots in the housings, and to which the guides are fixed.
Crapo Process. A method of *hot galvanizing.*
Crater. A depression or pipe formed in any run of weld metal in the last portion to solidify. It occurs where the arc has been broken or the flame removed.
Crater Cracks. Cracks radiating from the bottom of a *crater* and extending into the weld metal. Such cracks are liable to occur when the cooling contraction of the weld metal is drastically restrained, the crater itself acting as a *stress raiser.*
Cratering. (*a*) Excessive wear on the top surface of a cutting tool at a point just beyond the cutting edge where the chip passes over the tool. (*b*) As applied to *hard metal* tools, wear caused by a selective chemical attack of steel on tungsten-carbide grains under the influence of high local temperature of about 1300° C., generated by friction.
Crazing. (*a*) (*Worming*). A defect sometimes found in pack-hardened tools. It takes the form of surface markings "like the tracks of moth caterpillars under the bark of elm trees". (*b*) Crocodile skin marking formed on the surface of an ingot which has been teemed into an old mould whose inner surface bears a number of mosaic-like cracks.
C.R.C.A. An abbreviation for "cold rolled, close annealed", applied to sheet manufacture.
Creep. Slow but continuous deformation of metals under steady load. In lead and tin, for example, it occurs at room temperatures, and in steels at temperatures above 300° C., but steels vary considerably in their creep properties and certain alloy steels, such as those containing *molybdenum,* show considerable resistance to this effect.
Creep Curve. A graph relating two of the factors—stress, temperature, time and deformation—for constant values of the other two factors. It is usual to plot deformation with time, the load and temperature being kept constant.
Creep Rate. The rate of strain in a *creep test* under specified conditions of stress, temperature and time.
Creep Rupture Test. (*Stress to Rupture Test.*) A form of *creep test* conducted under a sufficiently high stress to cause the test piece to fracture during the test. The apparatus for carrying out the rupture test is similar to that employed for the creep test, except that a different instrument may be used for measurement of the elongation which may be quite high. It is customary to specify the test results in terms of time to fracture in hours, and the final elongation expressed as a percentage as in a tensile test.
Creep Test. A method of determining the plastic deformation of metals under a definite load at a definite temperature. Various criteria are used for assessing the behaviour of materials in a creep test, namely (i) as a definite creep rate, e.g. between X and Z hours (e.g. 24 to 72 or 25 to 35) or creep rate at 1000 hours, (ii) total deformation in a certain period of time. Owing to the lengthy nature of such testing where the service may extend to 10 years, or longer, considerable use is made of the extrapolation of

creep test results obtained for relatively short times.

Crespi Lining. A method of forming a basic lining in a hearth, or on other structural parts of the furnace. It consists in applying pure dry calcined dolomite, ground to the fineness of rice and flour respectively, to the part to be treated. The material is then tamped cold against the face by a suitable tool, thus forming successive layers until a unified and compact lining is formed. The lining is then transformed into a petrified mass by the action of heat during furnace operation. (C. 57.)

Cressing. (See SWAGING.)

Crevice Corrosion. The term applied when the corrosion attack on small areas is associated with crevices or recesses where small concentration cells may develop. (M. 90.)

Crimping. This consists of bending the edges of steel plate intended for the production of large diameter welded tubes. It is the preliminary operation before bending the whole plate into shape and is intended to prevent the formation of a flat surface near the longitudinal welded seam.

Cristobalite. The allotropic form of silica, stable between 1470° C. and its melting point (1713° C.). Two modifications exist: β-cristobalite, once formed, persists as a metastable form down to about 240° C. and then inverts, over a small range of temperature (*circa* 20° C.) to α-cristobalite, accompanied by considerable contraction. On reheating above 240° C., the reverse change occurs and the resulting expansion is one of the principal causes of *spalling* of silica bricks.

Critical Air Blast. (*C.A.B.*) The minimum rate of blast required to maintain the combustion of an already ignited bed of coke.

Critical Cooling Rate. The term, as applied to steel, represents the slowest rate of cooling which allows the formation of *martensite* or other special structural conditions. In many cases this amounts to the rate of cooling which will just suppress the pearlite/austenite transformation. (See also TRANSFORMATION RANGE.)

Critical Diameter. (D.) The maximum diameter which gives a specified *microstructure* at the centre in a given steel under standardized quenching conditions.

Critical Grain Growth. The drastic coarsening of the grains which occurs when certain steels, and in particular, mild steels, are subjected to a certain degree of cold work, and then annealed at a temperature below the upper *critical point.*

Critical Humidity. The relative humidity above which the atmospheric corrosion rate of a given metal increases sharply. (S. 88.)

Critical Point. A specific temperature and pressure at which liquid or gaseous phases reverse with the slightest change of conditions. (Cf. CRITICAL POINTS.)

Critical Points. The points of temperature at which changes of phase occur in steel. They are marked by the liberation of heat, *recalescence*, during cooling, and by absorption of heat, *decalescence*, on heating, thus resulting in halts or *arrests* on the cooling or heating curves. In steel there are several such points, the temperature for which depends largely on the composition of the steel. (See also TRANSFORMATION RANGE, IRON-IRON CARBIDE DIAGRAM and TRANSFORMATION TEMPERATURE.)

Critical Pressure. The pressure required to liquefy a gas at its *critical temperature*.

Critical Rate. (See CRITICAL COOLING RATE.)

Critical Size. That section of a steel which, on quenching, is just, but completely, hardened throughout.

Critical Solution Temperature. The temperature below which two mutually soluble liquid phases become only partially soluble in each other.

Critical Strain. The amount of cold work below which no recrystallization will take place on annealing, and above which coarse grain occurs.

Critical Strain Crystal Growth. The formation of crystals of abnormally large size arising in sheet or pressed shapes which have been strained to a critical degree.

Critical Temperature. (*a*) The temperature at which some change occurs in a metal or alloy during heating or cooling, i.e. the temperature at which an arrest or *critical point* is shown on heating or cooling curves. (*b*) The temperature at which alpha-iron loses its magnetic properties; about 770° C. for iron and steel. (*c*) The temperature above which a given gas cannot be liquefied by pressure. The pressure which will just liquefy the gas at the critical temperature is known as the *critical pressure*.

CrO_2. Chemical formula for chromium oxide.

CrO_3. Chemical formula for chromium trioxide, chromic acid.

Cr_2O_3. Chemical formula for chromium sesquioxide.

Crocidolite. (*Blue Asbestos, Blue Ironstone.*) A fibrous asbestos-like mineral

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Plate II.—Crucible process, teeming.

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at the edge. (*b*) Size of paper 15 × 20 in. (See also BOOK SIZES.)

Crozzling. (See CROCODILE SKIN.)

c.r.t. Abbreviation for cathode ray tube.

Crucible. (*a*) A refractory vessel or *pot* used in the *crucible process* for melting steel. In the production of these crucibles a specially selected clay, rendered stiff enough for use at high temperatures by the admixture of a small proportion of coke dust, is mixed and *tempered* by treading with the bare feet. A suitable quantity of clay is then placed in a previously oiled cast iron mould. This mould is open at both ends and its internal shape is that to be given to the outside of the crucible. The bottom of the mould is closed by means of a loose iron plate having a central hole to receive the projecting pin of the plug. The *plug* consists of a block of polished wood having the shape to be given to

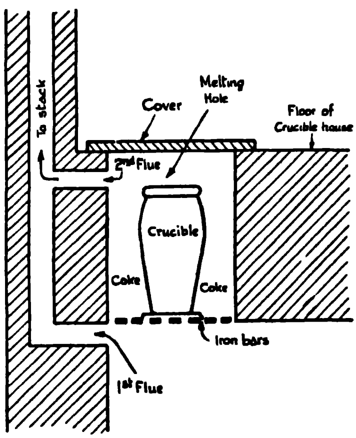

Fig. 3.—Diagrammatic cross section showing position of crucible in melting hole in the crucible process.

the interior of the crucible, and is provided with a central projecting pin at the bottom and a head at the top. After oiling, it is driven into the mould. The clay rises round the plug, the excess being cut off round the top of the mould. The plug is withdrawn and the upper walls of the crucible are curved slightly inwards by running a tool between the clay and the mould. The pot is then ejected from the mould by means of the iron plate at the bottom. The crucibles are then left to dry on the shelves of the *melting house* for a period of five to six weeks and immediately before using are subjected to an operation known as *nailing*, which consists of heating to redness for a period of some hours. The lids, made of the same clay as the pots, are treated similarly. Pots made in this way have a central hole in the bottom made by the projecting pin of the plug. This hole is closed, prior to charging, by fritting the crucible, by means of a handful of sand, on to the fireclay stand on which it is placed in the melting hole. The capacity of the crucible is usually about 56 lb. of molten steel. (See CRUCIBLE PROCESS.) (*b*) A small refractory vessel of about 1 to 2 in. in diam. used in chemical analysis. Quartz or fireclay crucibles are in general use for the ignition of residues, whilst somewhat larger crucibles of platinum or nickel are used for the fusion of alkalis, slags, etc.

Crucible Process. (*Huntsman Process.*) The process developed by *Benjamin Huntsman*, a Doncaster clockmaker, who established the first crucible steelworks in Sheffield in 1740. It was the first process in which the metal actually became molten during its production, hence the name, *cast steel*. The carefully calculated charge originally consisted of Swedish wrought iron and *blister bar*, with some white cast iron or pure charcoal to bring the composition to the desired carbon content, but this was modified in more recent practice and the advent of alloy tool steels naturally necessitated the addition of the essential alloying elements. These materials are broken up and put into the red-hot *crucible*, already in the *melting hole*, by means of an iron funnel, known as a *charger*. The lid is then adjusted and the "hole" charged with coke, which is of very high quality and low sulphur content. The melting hole, also known as the *coke-*, *fire-*, or *pot-hole*, is a refractory-lined chamber, about 3 ft. deep, with iron bars at the bottom and a movable refractory cover, and wide enough to hold two pots, the top being level with the floor of the *melting house* in which the work of *charging* and *teeming* is carried out. Removal of ash is done from a cellar below the melting house. Flues from the melting hole lead to a chimney and the draught is regulated by means of a damper. During melting, the carbon content of the charge tends to rise owing to the presence of coke dust in the walls of the crucible and there is a certain increase in the sulphur content due to the permeability of the crucible to the furnace gases. The silicon too is higher in the finished steel than in the charge and the high quality of crucible steel has been attributed to this fact. It is usual to melt the charge and then to retain the crucible in the melting hole

for a short time to allow the metal to attain the necessary super heat, during which period a slight reaction takes place between the metal and the crucible walls. The silicon thus reduced enters the steel in an active condition which is without doubt one of the helpful factors in the *killing* process. Apart from these effects, however, "what is put into the pot comes out of it". It is usual to add a little manganese to the crucible before teeming and a little aluminium is added as the ingot is poured. During teeming, the slag is held back by means of a *mop*, which consists of an iron bar, one end of which has been thickened by forming on it a knob of frozen slag. The crucible process has now been largely superseded by the *high frequency furnace* but it is still used to some extent for the production of special tool steels. (See Fig. 3 and Plate II.)

Crucible Steel. Steel made by the *crucible process*.

Crucible Zone. The *basin* of the *cupola*, where the molten iron and *slag* accumulate, i.e. the region between the sand bottom to just below the *tuyeres*.

Crush. Displacement of sand at *mould* joints or *core prints*, leading to the production of irregular-shaped cavities (*sand holes*) or projections on the *castings*. (I. 14.)

Crushed Slag. (*Air Cooled Slag*.) Slag which has been cooled by pouring in the molten condition on to a slag heap or pit and subsequently crushed and screened.

Crushing. The pushing out of shape of a *core* or *mould* when two parts of a mould, that do not fit properly, meet.

Crushing Test. A test for tubes in which a sample 1½ times the length of the outside diameter is compressed endwise until its outside diameter is increased by a specified percentage or one complete fold is made without sign of cracking. The test is also applied to longitudinally welded tubes, the pressure being applied in a direction parallel to its length.

Crustex Process. A process which prevents the formation of hard deposits on the walls and tubes of steam boilers. The functioning of the apparatus depends on the fact that if liquid containing lime or crystals is kept constantly agitated at high frequency, the particles are prevented from uniting to form a crust. In the present apparatus, a condenser is alternately charged and discharged from a source controlled by an intermittent mercury switch. The pulses are conveyed to the magnet-coil of an oscillator, in contact with the liquid, having in its field a tube of ferromagnetic material which is excited to magnetostrictive oscillations of 27,000 cycles per second. Oscillations of this frequency are thus imparted to the liquid and walls of the container and prevent the formation of scale. (E. 56.)

Crusting. A major cause of defects in ingots, produced by *uphill casting*. It consists of deoxidation products and eroded refractory rising to the surface of the metal and oxides, resulting from oxidation of the exposed top surface. Such products tend to migrate towards the mould wall and may be trapped in the rising metal. (B. 73.)

Cry of Tin. (See TIN CRY.)

Cryogen. A freezing mixture.

Cryogenic. A term referring to low temperatures or to apparatus for producing the same.

Cryohydrate. The solid which separates when a saturated solution freezes. It contains the solvent and the solute in the same proportions as they were in the saturated solution.

Cryolite. (*Cryolith, Ice Spar, Ice Stone*.) A fluoride of aluminium and sodium used for the production of aluminium. The deposits of the mineral are found principally in Greenland.

Cryolith. (See CRYOLITE.)

Crystal. A solid body, whose atoms are arranged in a definite pattern, the crystal faces or surfaces being an outward expression of the regular arrangement of the atoms and thus presenting a geometrical form, when the crystal can grow freely without the interference of adjacent crystals.

Crystal Analysis. Determination of crystal structure.

Crystal Boundaries. (See GRAIN BOUNDARIES.)

Crystal Indices. (*Crystallographic Axes*, or *Miller's Indices*.) Simplified and abbreviated expressions which have been derived from the parameters of a crystal form and are commonly used to give its relations to the crystallographic axes.

Crystal Nucleus. The minute crystal particle deposited by a supersaturated solution which acts as a focal point for further crystal growth, and upon which, according to its crystal form, the complete crystal is built up.

Crystal System. The group in which a crystal is classified according to its symmetry, i.e. *cubic, hexagonal, orthorhombic, tetragonal, monoclinic* and *triclinic*.

Crystal Thrust. The thrust exerted by the growth of a dendrite.

Crystal Unit. Unit of structure.

Crystalline. Composed of crystals. (A. 27.)

Crystalline Fracture. Fracture taking place between crystals and thus exposing flat surfaces which are bright and glittering because the metal has broken without distortion and so shows the crystal faces. In a tensile test piece it is evidence of brittleness. The coarseness of the fracture is a measure of the crystal size. (See also FRACTURE.)

Crystalline Powder. A powder that consists substantially of particles having a *crystalline* structure; most metal powders are crystalline. (G. 30.)

Crystallite Theory. The theory that when a metal is deformed plastically it breaks down into small relatively perfect fragments called *crystallites*. The question of whether the line broadening observed in back-reflection X-ray patterns from cold-worked metals is caused by small fragments of crystal or whether it is due to severely distorted lattices has not yet been determined. There is also the possibility that, under certain conditions of straining, a metal crystal may be broken down into much larger sub-units or cells. (M. 107.)

Crystallites. (See CRYSTALLITE THEORY.)

Crystallization Interval. (See SOLIDIFICATION RANGE.)

Crystallogram. A photograph of the X-ray diffraction pattern produced by a crystal.

Crystallographic Axes. (*Crystal Indices.*)

Crystallographic Planes. Any set of parallel and equally spaced planes that may be supposed to pass through the centres of atoms in crystals. As every plane must pass through atomic centres and no centres must be situated between planes, the distance between successive planes in a set depends on their direction in relation to the arrangement of atomic centres.

Crystallographic System. Any of the major units of crystal classification, embracing one or more symmetry classes.

Crystallography. The study of the forms, properties and structure of crystals.

Crystalloid. An obsolete term for a substance which dissolves to form a true solution.

Crystalloluminescence. Light emitted during precipitation of crystals from solutions.

C.S. Commercial Standard (U.S.A.).

Cs. Chemical symbol for *caesium*.

C.S.A. Canadian Standards Association.

C.S.I.R.O. Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia.

C.T. Diagram. Cooling Transformation Diagram.

C.T.I. Abbreviation for Comitato Termotecnico Italiano. The Italian body issuing standards for refractory materials.

C.T.S. Weldability Test. (See CONTROLLED THERMAL SEVERITY WELDABILITY TEST.)

Cu. Chemical symbol for *copper*.

Cubbling. (See CABBLING.)

Cube-centred. Concerning space lattices, *body-centred cubic*.

Cubic. A term relating to crystals having three equal axes which are mutually perpendicular.

Cup and Cone. (*a*) A type of fracture occurring in tensile test pieces from steels possessing reasonable *ductility*, and containing no local abnormality where the necking occurs after maximum stress. The fracture gives one surface with a cup-like contour, and the other in the form of a cone, fitting the cup. This is accepted as evidence of *toughness* and uniformity of structure. (*b*) (See BELL AND HOPPER).

Cumberland Process. A process for the prevention of electrolytic corrosion. It employs an external source of electrical current, thus polarizing the system. (S. 21.)

Cupola. The furnace most commonly used for the production of iron castings in the *foundry*. It is a straight shaft furnace consisting of a circular shell of steel plates lined with firebrick, open at the top and bottom. There are numerous modifications in design. In a typical *drop bottom furnace*, the shaft stands on a *bed plate* with a central opening, the size of the inside of the lining. This opening is closed by two hinged cast iron doors, protected from the heat of the furnace by a bed of sand. These doors support the charge and are opened at the end of the heat to drop out (*dump*) the residue of iron, coke and slag in the furnace. The bed plate is supported on splayed cast iron legs which stand on a foundation of concrete or brick. The charge, consisting of a bed of coke placed on the bottom of the hearth and extending above the *tuyeres*, on which the first layer of iron is placed and thereafter alternate layers of iron and coke with limestone as flux, is introduced through the *charging door*, situated about half-way up the stack. Surrounding the shaft, near the bottom, is a *windbox* or jacket through which air is driven, by means of a *fan* or *blower*, to the *tuyeres*, which may be arranged in two or more layers. The air is generally cold; a furnace in which the blast is slightly preheated is termed

a *hot blast cupola*. The *breast*, an opening at the bottom of the furnace, at which the fire is lighted, is made of fireclay and is built up anew before each heat. The *well* is directly below the *tuyeres* and is a relatively inactive zone. It collects the metal and slag melted from the stock above the bed and permits the two to separate. The *taphole*, through which the molten iron is drawn off, is situated in the breast, and a spout, which projects below it, guides the metal into a ladle. The taphole is closed with a conical clay plug known as a *bott*. The *slag hole* is at the back of the furnace, slightly below the *tuyeres*, but at a higher level than the taphole. The burnt gases escape through the top of the furnace which is open apart from a *spark arrester* which consists of a metal shield so placed as to prevent the emission of sparks. (See Fig. 4.)

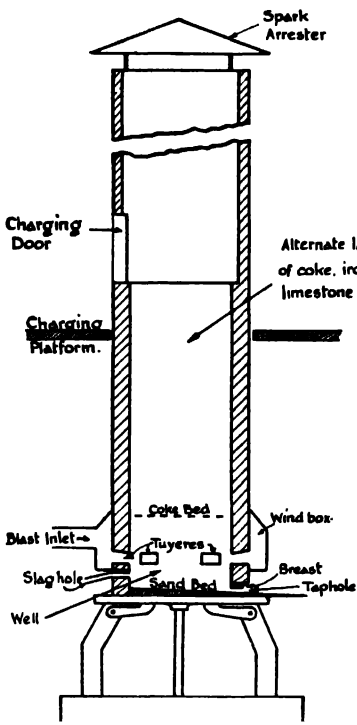

Fig. 4.—Diagrammatic cross section of cupola.

Cupola Blower. (See BLOWER.)

Cupolette. A small *cupola* in which the preheating space between the top of the bed coke and the top of the stack is considerably curtailed.

Cuppiness. An internal defect in *wire-drawing* which leads to fracture of the *cup and cone* type. It may be caused by excessive cold work (*overdrawing*) without adequate intermediate *annealing* or by *segregation* where the hard centre, being less ductile than the surface, tears and starts the fracture.

Cupping. A process for the production of seamless tubes. It consists in pressing a cup from a flat plate or disc, which has just been heated to forging temperature, and progressively elongating it into a tube by decreasing the diameter while it passes through a series of reducing dies. (See PUNCHING.) (W. 74.)

Cupping (of Wire). (See CUPPINESS.)

Cupping Tests. Methods of testing the suitability of sheet material for *cold pressing* operations. In the most widely employed forms of this test a piece of sheet steel is held between annular steel jaws and the rounded end of a steel plunger or ball is pressed against one face of the sheet, the other face of the sheet being unsupported. A cup or depression is thus formed in the metal, the deformation being continuously increased until failure occurs. The depth of the cup at failure is usually taken as a measure of the *ductility* of the material. Such tests include the *A.E.G.*, *Amsler*, *Avery*, *Erichsen*, *Guillery*, *Olsen* and *Persoz*. For other modifications of the cupping test see JOVIGNOT, K.W.I., and N.P.L. tests. (G. 37.)

Cupriferous. Containing copper.

Cupro-Nickel. An alloy containing about 70% copper and 30% nickel. It possesses good resistance to corrosion by sea water and for this reason is widely employed for condenser tubes.

Cupro-Scheelite. (See SCHEELITE.)

Cupro-Tungstite. A synonym for *cupro-scheelite*. (See SCHEELITE.)

Cuprodescloizite. ($2PbO.2CuO.V_2O_5.H_2O$.) A vanadium ore.

Curie. A unit of measure of the intensity of the radiation available from a given radioactive substance. It is defined as the amount of radioactivity obtained from one gram of radium.

Curie, Marie. (1867–1934.) Born in Warsaw, she received the Nobel prize for Chemistry in 1911 and in 1919 became Professor of Radiology at Warsaw. (See CURIE, PIERRE.)

Curie, Pierre. (1859–1906.) A French physicist who jointly with his wife, *Marie Curie*, discovered *radium* in 1898.

Curie Point. (See MAGNETIC CHANGE POINT.)

Curled Hoop. Hoop so produced that it will take a circular form.

Curran and Morehead Creep-Test Machine. A direct-load creep-test machine, in which a convection type of furnace is used. The atmosphere of the furnace is continuously circulated round the specimen and shackles, heat being

applied at a remote point by passing the circulating air through a heating chamber. Temperature control is achieved by means of a thermocouple, attached to a potentiometer controller, inserted into a drilled hole extending axially through the threaded end to the shoulder. This couple maintains the temperature of the specimen constant within very narrow limits. Another couple, placed in the other end of the specimen, is connected to a potentiometer recorder and furnishes a continuous record of temperature fluctuations within the specimen. A welded framework of structural steel rests on concrete piers which are independent of one another. The test specimens and furnaces are supported directly on the framework. (C. 62.)

Curran's Reagent. An etchant for stainless steels. It consists of ferric chloride 10 g., concentrated hydrochloric acid 30 ml., and water 120 ml. The surface of the specimen is swabbed with cotton-wool soaked in this solution. As a general rule, the etching time does not exceed 30 seconds.

Current Density. The average current per unit area of surface of an electrode, usually expressed as *amperes* per square foot or per square decimetre.

Current Efficiency. In an electrochemical process, the ratio of the mass of the substance liberated or chemically changed to the theoretical amount computed from *Faraday's Law*.

Current, Exciting. The *rms.* value of the total current supplied to a coil, linked with a magnetic core. (A. 28.)

Current, Magnetizing. The *rms.* value of the quadrature component (with respect to the induced voltage) of the exciting current supplied to a coil, linked with a magnetic core. (A. 28.)

Curtaining. (See DOUBLE SKIN.)

Curtains. A defect found on galvanized sheet due to uneven flow of zinc on the surface giving a rough and cloudy appearance.

Custom's Entry. Description, together with value and weight of goods, which the law requires shall be provided by a shipper or importer for the use of the Custom's Authority.

Cut. (*a*) A term describing the characteristic of the teeth of a file. The *single cut file* has an unbroken course of teeth or chisel cuts across its surface, parallel to each other, but usually at an oblique angle to the length of the file. This type makes a smooth cut. In a *float cut*, the teeth are cut square across the face of the file and are more widely spaced. Such files are used for filing soft metals and cork, the wide space between the teeth enabling the file to free itself from the cuttings. The *double cut* file has two courses of chisel cuts crossing each other, both oblique across the file blank; the first course is called the *overcut* and the second course the *upcut*. Thus the teeth of double cut files are points whilst the single cut teeth are chisels. In a *bastard* cut the file teeth are of a medium degree of coarseness; a *rough cut* file has the smallest number of teeth to the inch and the *fine cut* the greatest number. *Rasp cut* differs from the above in that the teeth are not placed in parallel rows, but are staggered, each tooth being put in specially by the pointed tool. (*b*) (See KERF). (*c*) (See FRACTION.) (*d*) An irregular rough area on the surface of a casting.

Cut Offs. A pair of blades used to cut off a forging from the bar on completion of forging.

Cut Weight. The weight of material required to produce a single forging. This includes *tonghold*, *flash* and loss due to scaling.

Cut Wire Shot. A cleaning and *peening* agent consisting of small lengths of high carbon steel spring wire used in *shot-blasting* where they are changed into small spheres by use. It is claimed that this type of shot has a much longer life than the conventional kind. (C. 12.)

Cutlers' Company. (*a*) The Company of Cutlers in Hallamshire, The Cutlers' Hall, Church Street, Sheffield, 1, is an ancient Guild incorporated by Act of Parliament under James I in 1624. It is invested with "powers for the good order and government of makers of knives, scissors, shears, sickles, and other cutlery wares". One of its most important and earliest duties was to grant Corporate Marks. On the foundation of the National Register of Trade Marks in 1875, the Law recognized the right of the Cutlers' Company to grant Trade Marks to manufacturers carrying on business in the district of Hallamshire and six miles compass thereof. In 1888, the Cutlers' Company became a branch of the Patent Office, for the granting of Trade Marks. (*b*) The *Worshipful Company of Cutlers in London*. In the London area, the cutlery trade originally appears to have been carried on in three branches, (i) The Forgers of Blades (Bladers), (ii) the Makers of Hafts, (iii) The Sheath Makers for Knives, Swords, and Daggers. These were all incorporated as one united body by King Henry V in the year 1413, by the style and name of "The Master Wardens and Commonalty of the 'Mystery of Cutlers of London' ".

Other Charters have been granted to the Company but that under which it is now governed is that granted by James I in 1607. The site for the Hall of the Cutlers' Company was purchased in 1451, in Cloak Lane, Dowgate Hill, and this remained the address of the Cutlers' Company for nearly 500 years. The present address is 4 Warwick Lane, London, E.C.4.

Cutlery. The following table gives the analyses of various types of cutlery steel:

	C %	*Mn* %	*Si* %	*Cr* %
Stainless cutlery	0·30	0·22	0·12	13·0
Shear steel table blades	0·80/0·95	0·05	0·07	—
Shear steel carvers	0·80/0·95	0·05	0·07	—
Cast steel table blades	0·80/0·95	0·22	0·12	—
Cast steel carvers	0·80/0·94	0·22	0·12	—
Ordinary steel table blades	0·45/0·50	0·50/0·80	0·12	—
Ordinary steel carvers	0·45/0·50	0·50/0·80	0·12	—
Cast steel pocket knives	0·80/1·0	0·22	0·12	—
Cast steel razors	1·4/1·5	0·22	0·12	—

Cuts. Defects in a casting resulting from *erosion* of the sand by the metal flowing over the mould or cored surface. (A. 26.)

Cutter. (See CUTTING BLOWPIPE.)

Cutting. (*a*) *Gas.* A process of severing metal by means of the chemical action of oxygen on metal at a high temperature. (*b*) *Carbon Arc.* A process of severing metal by the heat of the carbon arc. (*c*) *Metal Arc.* A process of severing metal by the heat of the metal arc. (*d*) The operation of producing teeth on a file (See CUT). (*e*) The operation of feeding strip from a coil into a straightening machine and shearing the product into straight flat lengths. (*f*) (See SHEARING.)

Cutting Blowpipe. A device used in gas cutting for mixing and controlling the gases used to heat the material to be cut, and for controlling and directing the oxygen jet severing the metal. It is sometimes called a *cutter*.

Cutting Edge Back Rake. (See RAKE.)

Cutting Edge Side Rake. (See RAKE.)

Cutting Fluids. (*Coolants.*) Liquids used in machining operations and allowed to flow over the cutting tool to disperse the heat generated in separating the chip from the work. Additional functions of the coolant are to reduce the friction between the chip and the tool, and to wash away the chips from the cutting zone. Such fluids vary widely according to the nature of the cutting operation and the composition of the work, but in general they consist of a mixture of oils or emulsions, e.g. a mineral lard oil, to which, for certain types of work, sulphur may be added, or an emulsion of lard oil, soft soap and water.

Cutting Nozzle. (*Cutting Tip.*) The part of a *cutting blowpipe*, adjacent to the preheating flame and the cutting jet, through which the gases issue.

Cutting Out. A process of removing some of the sand from a mould in order to allow for a deviation from the pattern.

Cutting Over. Turning over sand by shovel or otherwise to obtain a uniform mixture.

Cutting Shellac. Dissolving shellac in alcohol. (A. 26.)

Cutting Speed. The peripheral or surface speed of the work with respect to the tool, e.g. in turning the cutting speed is measured on the uncut surface of the work ahead of the tool and is usually measured in feet per minute.

Cutting Tip. (See CUTTING NOZZLE.)

Cutting Torch. A device used in oxygen cutting for controlling and directing the gases used for preheating and the oxygen used for cutting the metal. (A. 37.)

Cyanide Hardening. (See CYANIDING.)

Cyaniding. (*Cyanide Hardening.*) The process consists of introducing carbon and nitrogen into the surface of steel by heating it to a suitable temperature (e.g. 760° to 845° C.) in a molten bath of sodium cyanide, or a mixture of sodium and potassium cyanide or of salts to which calcium cyanamide has been added, and quenching in water or oil. The process is used where a very thin case of high hardness is required. An immersion of 5 to 10 minutes usually suffices. (G. 63.)

Cyanite. An aluminium silicate similar to *andalusite* and *sillimanite* ($Al_2O_3 . SiO_2$); on heating, decomposition to *mullite* and siliceous glass begins about 1100° C.

Cybernetics. The science of automatic control.

Cyc-Arc Stud Welding. In this process the actual welding operation is automatic; the operator loads the stud into the tool chuck, placing the coned end of the stud in the welding position, presses trigger switch on to the tool thus starting the welding cycle which welds the stud instantaneously. The striking or formation of the arc between stud and plate and the maintenance of the arc for a pre-determined period, the return of the stud to the pool of molten metal in the plate and the interruption of the welding current, are all part of the arc-cycle, controlled automatically by an electronic timing mechanism in the controller unit. The speed of operation is restricted only by the loading of the stud into the chuck and the locating of the stud in welding position.

Cycle-Sintering. This differs from ordinary sintering in that temperature is fluctuated above and below the sintering temperature in a predetermined cycle, e.g. by cycling the temperature every 5 minutes from 15° C. above to 15° C. below the correct sintering temperature, or through the alpha-gamma transformation temperature. (H. 31.)

Cyclic Annealing. A method of *interrupted quenching* in which the steel is first heated to the austenitizing temperature, approximately 815° C., and then quenched in another bath at a temperature between 595° to 705° C. where it remains for the time indicated by the *S-curve* for that particular steel to complete transformation. The *austenite* transforms directly to the desired soft structure of *ferrite* and *pearlite*. The steel is then quenched in air or water as rapidly as possible. Depending on the analysis and mass of the steel, the total operation takes from 30 minutes to a few hours. (A. 4.)

Cyclic Humidity Accelerated Corrosion Test. A test developed by General Motors Corporation to simulate the worst conditions of automotive exposure. The test conditions include a temperature of 52° C., a slow humidity cycle, and the use as dip of a dilute electrolyte of sodium and calcium chloride, to resemble a salt-filled slush generated on city streets during the winter. A small amount of sulphuric acid is added to the dip solution to allow for the presence of sulphur compounds in the atmosphere. Such conditions are found to secure the formation, after an initial period, of an almost non-protective rust, closely similar to that appearing on sheet steel exposed in service under the conditions described. (A. 32.)

Cyclically Magnetized Condition. A magnetic material is in a cyclically magnetized condition when, under the influence of a magnetizing force which varies cyclically between two specific limits, its successive hysteresis loops are identical. (A. 28.)

Cyclograph. An electronic instrument in which the piece of metal to be tested is inserted in a coil which is part of the instrument and also part of a tuned circuit; the test piece thus becomes the core of the coil and produces measurable power losses in the tuned circuit which are used to produce cathode-ray oscillograms on screens incorporated in the instrument panel. The changes in the patterns produced on the screen, as different test pieces are inserted in the coil, indicate changes in such properties as *case* depth, *core* hardness and carbon content. The instrument is particularly useful for sorting steels according to chemical analysis or heat treatment. (G. 61.)

Cyclone Furnace. A forced circulation heat treatment furnace. The gas circulates at the rate of 176 ft. per minute. The furnace is designed to operate at a maximum temperature of 760° C. and is either gas fired or electrically heated.

Cycloscope. A machine for measuring at any moment the velocity of rotation.

Cypritic Steel. A steel containing approximately 15% chromium and 9% copper. It is claimed to be resistant to corrosion in the atmosphere and tap water, but its corrosion-resistant properties are inferior to the conventional austentic chromium-nickel steels of the 18/8 type. (L. 35.)

Czochralski Method for Determination of Non-Metallic Inclusions. This method is based on the determination of differences in the electrical resistance of non-metallic inclusions.

A sharply pointed needle is moved to and fro across a polished steel surface, and the deflections, shown by a milliammeter connected to the needle, the specimen, and a 4-V. accumulator (through a resistance), are observed. Each decrease of the current is found to be related to a defect, the size of which varies with the extent of the deflection. Inclusions smaller than about 0·1 mm. in diameter cannot be detected by this method. (C. 63.)

Czochralski's Reagent. An etchant for iron or steel, consisting of a solution of 10% to 20% ammonium persulphate in water.

D

D. (*a*) Chemical symbol for *deuterium*. (*b*) *Critical diameter*. (*c*) A French symbol for a striated type of fracture with parallel lines.

δ. (*a*) (See GREEK ALPHABET). (*b*) (See DELTA IRON).

δ_5, δ_{10}. Symbols used in France and Germany to indicate the gauge length of a test piece in relation to its diameter, with reference to the per cent elongation, e.g. δ_5 indicates that the gauge length of the test piece is five times the diameter, whilst δ_{10} indicates it is ten times the diameter.

D_1. *Ideal diameter*.

"D" Shell Moulding. (*Fordath Process.*) A modification of the normal *shell moulding* process based upon the use of

sand and a special oil which serves as the binder. Such a mixture can be handled by normal core-blowing equipment and moulds are in effect produced by a core-making technique. For this purpose a pattern which provides the desired cavity form, is employed in conjunction with a contour plate. The latter follows, generally, the form of the pattern, but need not duplicate that form with any particular accuracy. Sand, treated with the binder oil, is blown into the space between pattern and contour plate, and the spacing of the two determines the average thickness of the shell. Local incidental variations in thickness are not important, but variations may be deliberately introduced when it is desired to obtain greater shell strength over certain areas. Alternatively, the contour plate may be of such a form as to provide reinforcing ribs on the shell. (M. 50c.)

Daae Producer. A gas producer characterized by a revolving grate and ash-pan which enables the ash to be removed continuously. Another feature is that only part of the blast is introduced at the centre, the remainder entering through a large number of small openings in the revolving grate. (B. 61.)

Daelen Mill. An early type of *universal rolling mill* provided with both vertical and horizontal rolls so that a part could be rolled on all sides in one operation.

Daeves's Reagent. An etchant used to distinguish carbides in chromium steels and tungstides in high speed steels. The solution contains 20 g. potassium ferricyanide and 10 g. potassium hydroxide in 100 ml. of water. In the cold it etches carbides in chrome steels and tungstides in about 20 seconds but about 5 minutes in boiling solution is required to colour cementite.

D.A.L. Process. (*Diffusion Alloys Ltd.*) A method of coating one metal with another in which the articles to be treated, e.g. of steel, nickel or copper, are heated in the presence of a halide, preferably a chloride, e.g. ammonium chloride, mixed together with coating metal in powdered form, e.g. ferrochromium. The reaction is carried out in a stainless steel vessel which is sealed by means of a substance, such as a silicate or borosilicate which will melt or become sufficiently soft to flow at the temperature of the reaction but which is solid at atmospheric temperatures. The time and temperature of the treatment varies from say 6 hours at 750° C. in coating copper rods with aluminium, to 6 hours at 1100° C. in chromizing steel. (D. 33.)

Dall Tube. An instrument for measuring fluid flow. (I. 74.)

Dalton, John. (1766–1844.) An English chemist. The first compiler of a table of atomic weights, and the formulator of the atomic theory.

Dalton's Law of Definite Proportions. In every sample of each compound substance the proportions by weight of the constituent elements are always the same, i.e. when elements combine to form a compound they do so in definite proportions by weight, these definite weights being known as *combining weights*.

Dalton's Law of Partial Pressures. The pressure exerted by a mixture of gases is equal to the sum of the separate pressures which each gas would exert if it alone occupied the whole volume.

Damage Line. The line in the normal *S/N diagram* which indicates the stress and the corresponding alternations of stress to which a particular fatigue test piece can be subjected without damage to the *fatigue limit*.

Damaging Stress. The minimum stress which, if exceeded, would render material unfit for service before the end of the normal expected life.

Damascene Process. (*a*) (*Damascus Blade.*) Steel, made by this process in India from very early times and later in Iran, found its way into Western Europe, through Syria and Palestine, during the Middle Ages. The process consisted of heating together *wrought iron* and charcoal in a crucible and cooling extremely slowly. The cake of steel thus obtained, containing from about 1·2% to 1·8% carbon, was cut in two and each piece was formed into a blade by repeated heating and hammering. The blade so formed was characterized by its beautifully patterned or "watered" surface, which varied according to the quality of the steel and the manner of forging, from the "grape vine pattern" to the much prized "Mahomet's ladder" consisting of oblique bands crossing the blade at intervals. Such blades possessed remarkable cutting properties combined with very great toughness. Later, blades were made by this process at *Toledo* in Spain. (B. 34.) (*b*) The Spanish art of inlaying steel with gold which originated in 1865. At first it was done by a method of stamping and later by a method known as "knife scratching" or "striping". Fine "stripes" are traced in the steel with a knife. Pure gold wire is inlaid in this stripe and hammered in with fine steel punches. The article is then blued, the steel remaining black and the gold projecting from the

hollowed-out stripe. The filigree work is then chiselled and some parts are burnished to throw up the contrasting colours. Silver alloy can also be used to give a beautiful variation in tone.

Damascus Blade. (See DAMASCENE PROCESS.)

Damping. (*Crackless Plasticity, Elastic Hysteresis, Internal Friction, Mechanical Hysteresis Loss.*) A term applied in connection with vibrating mechanical systems to denote the operation of influences which by resisting the motion and absorbing energy from the system, restrict and tend to stop the vibration. An undamped free vibration would persist for ever, but such conditions do not exist in nature and all free vibrations die down after a time. (H. 29.)

Damping Down. Stopping up the air inlets of a blast furnace when working is suspended.

Dancer Rolls. Rolls for the control of the rate of travel of coiled strip through a pickling bath in continuous operations.

Daphnite. An iron aluminium silicate.

Darby, Abraham, I. Darby Abraham, II. In 1708, Abraham Darby I, took over the lease of furnaces in Coalbrook Dale, and it is generally agreed that it was in these works that the successful smelting of iron with coke instead of charcoal was first carried out. Dr. Percy attributes the development to Abraham Darby II (1711–63) but, other authorities quote evidence which suggests that coke was being used for this purpose by Abraham Darby I in the years 1708–9.

Darby Process. A method of carburizing *open hearth steel* which consists of treating the molten steel with carbon in the form of charcoal, graphite or coke.

Dark Field Illuminator. A device incorporated in certain types of inverted metallurgical microscopes by means of which the specimens may be obliquely illuminated on all sides.

Darmold. An ingot mould coating consisting of a colloidal graphite suspension resembling heavy black paint. (I. 36.)

Dashpot. A device for damping out irregular disturbances and vibration. It generally consists of a piston, attached to the part to be damped, fitting loosely into a cylinder containing a suitable fluid, such as oil. The tendency of the piston to move under the action of the disturbing force is opposed by the resistance offered to the flow of the fluid.

Dasymeter. An instrument for testing the density of gases. It consists of a thin glass globe, which is weighed in the gas or gases under observation, and then in an atmosphere of known density.

Datum Points. (See POP MARKS.)

Daubing. (*a*) The operation of filling cracks in *cores* or repairing the lining of a *cupola* after the *heat*. (*b*) The material used for this purpose, e.g. ground firebrick or ganister, mixed with fireclay.

Davis Wheel. A railway tyre consisting of a soft plate and boss, and a wear resistant tread of water toughened manganese steel, cast integrally with it.

Davy, Sir Humphrey. (1778–1829.) An English chemist, who first isolated potassium and sodium. The inventor of the Davy lamp.

Dawe Ultrasonic Thickness Gauge. The instrument is designed to measure the thickness of plating. It is based on the principle that a quartz crystal is caused to vibrate electrically and is placed against the surface of the plate to be measured. In practice, the basic frequency is varied by turning a calibrated dial, and the resonance point is noted by headphones and a meter in the instrument. (S. 59.)

D.B. (*Decibel.*)

D.C. (*a*) *Direct current.* (*b*) An abbreviation used in the manufacture of tinplate for a standard thickness of 0·016 in.

Deactivation. The process of prior removal of the active corrosive constituents, usually oxygen, from a corrosive liquid by controlled corrosion of expendable metal or by other chemical means. (E. 10.)

Dead Annealing. Heating steel to a temperature above the critical range, holding at that temperature, followed by very slow cooling, in order to develop the greatest possible commercial softness or ductility.

Dead Banking. A method of suspending the operation of a blast furnace in which all combustion in the furnace ceases and the *stock* is cooled, thus preserving all the coke with the metallics in the stock partially reduced and in condition for final reduction when working is resumed. (Cf. BANKING.) (R. 26.)

Dead Burned. A term applied to refractory materials which have been baked at temperatures which are sufficiently high to render them resistant to moisture and less liable to *after contraction*.

Dead Burned Magnesite. An inert product of high temperature calcination, consisting of the natural magnesium oxide, periclase, with some iron, lime, silica and alumina as impurities.

Dead Cast. A coil of wire in which the *waps* are in circles of uniform diameter.

Dead Head. The useless metal projecting on a casting which corresponds to the position of a *riser* in the *mould*.

Dead Hole. A shallow depression in a casting.

Dead Load. (*Dead Weight.*) A load which is steady or invariable, such as the weight of a fixed part of a machine or a gradually applied load as in a testing machine. (Cf. LIVE LOAD.)

Dead Melted Steel. A charge of steel at the end of the steelmaking operation, which has been finished under a non-oxidizing slag, the last traces of oxygen having been removed by an addition of ferro manganese or ferro silicon. Such steel solidifies quietly in the mould without the liberation of gas, with the formation after solidification, of a central *pipe*, due to contraction.

Dead Mild Steel. (See DEAD SOFT STEEL.)

Dead Pass. (See PASS.)

Dead Soft Steel. (*Dead Mild Steel.*) Steel having a very low carbon content, about 0·10% to 0·15% and usually not more than about 0·12%.

Dead Steel. (*a*) Fully *killed* steel which sinks quietly in the ingot mould during solidification. (*b*) The term is also applied to steel which fails to respond to heat treatment due to the fact that it has been worked at excessively high temperatures, e.g. 1300° to 1350° C.

Dead Weight. (See DEAD LOAD.)

Dead Weight Machine. A machine in which the load is applied by weights without the use of levers or other means of mechanical advantage. (B. 100.)

Deblanchol Rotary Furnace. (*Fofumi.*) A cylindrical refractory-lined shell, provided with a gas-flue leading to a recuperator at one end, and a fuel and air port at the other. Air for combustion is preheated in the recuperator, and oil firing is adopted. The furnace may be used for melting grey iron and non-ferrous metals; it is claimed to have many advantages, including simplicity, low cost, close control and speed of melting. (H. 45.)

De-burring. A special type of tumbling with some of the characteristics of burnishing, the objective being the removal of metal from a localized area with minimum dimensional change on the work as a whole. (M. 143.)

Debye-Scherrer Method. In X-ray metallography, a method using a monochromatic (or polychromatic) X-ray beam defined by pinholes, an aggregate of small crystals oriented more or less completely at random and a photographic film bent into an almost complete cylinder with axis perpendicular to the X-ray beam at the crystalline specimen; almost indistinguishable from the *Hull method*; sometimes called the *powder method*. (A. 27.)

Decalescence. (See IRON-IRON CARBIDE DIAGRAM.)

Decantation. The separation of a liquid from a residue or a liquid of higher density by carefully pouring off the supernatent layer without disturbing the heavier material which has previously been allowed to settle at the bottom of the containing vessel.

Decarburization. The loss of carbon from an iron base alloy as a result of heating in a medium which reacts with the carbon. The degree of decarburization decreases from surface to interior. At the surface there may be complete loss of carbon, leaving a zone of ferrite. The next zone will have only a partial loss gradually decreasing to the normal carbon content of the steel. (See also BLACKHEART MALLEABLE CAST IRON.)

Dechenite. A vanadium ore consisting of lead meta-vanadate.

Dechenne Process. A method of removing *pipe* and impurities from steel intended for making tyres and hoops. The anvil of the forge hammer or press is provided with a hemispherical hollow of suitable size; the ingot, large enough for one disc, is placed on it upside-down. The ingot is then flattened down to approximately the thickness of the tyre to be made, and the piped and segregated metal is forced into the hollow of the anvil. The disc is then placed on a ring support, and the centre is punched out, the piped and segregated metal being removed at the same time. (D. 12.)

Dechesne Jarring Forehearth. The forehearth, which is of rectangular form, is placed under the trough of a cupola or steel furnace, and when filled with molten metal is subjected to a jarring motion imparted by a rotating cam shaft passing under one end of the forehearth, the other end resting on a rocker. The greater part of the sulphur present in the cast iron goes, immediately, into combination with the manganese, iron sulphide forming only when the manganese is saturated; the manganese sulphide tending to rise to the top and pass into the slag. (I. 85.)

Decibel. (*D.B.*) (*Sensation Unit.*) The smallest difference in sound intensity which the average human ear can detect. The unit of power level difference used in telephone engineering.

Decomposition. The breaking up of a compound into simpler molecules or atoms whose properties may differ from each other or from the original substance.

Decomposition Potential. The practical minimum potential difference necessary to decompose the electrolyte of a cell at a continuous rate. (E. 10.)

Decrepitation. In general, the term refers to the behaviour of certain minerals on heating when small fragments fly off with a crackling noise. In particular, the term is applied to the cracking of ores on *calcination*.

Deep Drawing. A method of forming blanks of mild steel or non-ferrous sheet or strip into a hollow cylindrical body, by means of *dies*. The process involves reduction of wall thickness and considerable plastic distortion of the metal. *Cupping tests* are used as criteria of the suitability of the material for this purpose. (J. 16.)

Deep Drawing Steel. Low carbon steel specially rolled for *deep drawing*. It must possess *high ductility*, fine *grain size*, and be as free as possible from *preferred orientation*.

Deep Etching. (*Macroetching.*) Etching, for examination at low magnification, in a reagent that attacks the metal to a much greater extent than normal in micro-examination. Gross features may be developed, i.e. abnormal grain size. It provides a means of revealing *flow lines* or defects such as segregation or cracks. (See MACROSTRUCTURE.)

Deep Freeze Treatment. (See SUB-ZERO TREATMENT.)

Deep Seam. A defect which may appear as a depression both on the outside and inside of a butt welded pipe.

Deep Welding. A process of *oxy-acetylene* welding, which requires a deep, hard and concentrated flame, directed at right angles to the length of the joint. The use of non-bevelled, relatively close edges ensures maximum economy in the use of material. The flame is introduced deeply into the gap, and the actual tip of the cone, where the heat is most concentrated, should reach the bottom edges of the joint, thus ensuring complete weld penetration and fusion. (G. 70.)

D.E.F. Specifications. A series of general specifications for inter-services equipment drawn up by the Engineering Standards Co-ordinating Committee of the Ministry of Defence, published by H.M. Stationery Office.

Defectoscope. An electro-magnetic instrument for the detection of defects in wire rope. Two types of instrument are available using D.C. or A.C. current respectively. The D.C. defectoscope consists of a coil which induces a magnetic field in the direction of the axis of the rope and a secondary coil which feeds the induced voltage into a filter circuit connected to an amplifier and a recording instrument. To obtain a magnetic field in the rope, the windings are oscillated by a vibrator. The windings are made in two semi-circular halves to enable them to be fitted over any part of the wire rope. In the A.C. defectoscope the resistance is connected across the secondary winding and the secondary voltage is fed from a bridge circuit, i.e. from the centre point of the secondary winding and a variable point of the resistance, to the measuring circuit. The D.C. instrument is much more sensitive than the A.C. and it can detect a single broken wire inside the rope. Maximum sensitivity for detecting faults is obtained for a field of about 20,000 *gausses*.

Define. In X-ray metallography, to limit in angle, as by slits or pinholes; to *collimate*. (A. 26.)

Definite Proportions. (See LAW OF DEFINITE PROPORTIONS.)

Deflection. (*a*) Deviation from a straight line. (*b*) The movement of the hand of a recording instrument. (*c*) The deformation of a spring under load.

Deflectometer. An apparatus for making *transverse bend tests* on cast iron and automatically recording load deflection curves.

Deflocculation. (See DISPERSION.)

DeForest Rayflex Fatigue Machine. A vibratory flexural machine in which the specimen under test consists of a long strip or bar, supported at the nodes on V supports for free vibration. The specimen is put into vibration by a variable frequency alternating current magnet, tuned to the natural period of vibration of the specimen. Stress is controlled by varying the current in the alternating current magnet and stress is determined from the amplitude of vibration of the specimen which in turn is measured by viewing the vibrating specimen through a microscope with micrometer eyepiece. The specimen is its own dynamometer. (A. 35.)

DeForest Scratch Gauge. A hardness measuring instrument in which a sharp scribe is dragged over a polished surface. The inscribed record is then read off under a microscope.

Deformation. Change of shape due to stress. *Elastic deformation* is produced by stress within the *elastic range*, i.e. the range within which the material will return to its original shape when the load is removed. Permanent or plastic deformation occurs when the applied stress is greater than the *elastic limit* of the material. In the latter case the material does not return to its original

dimension on removal of the load; it is permanently deformed, *plastic flow* having taken place. In sand, the change of linear dimension of a sand mixture resulting from stress. (A. 26.)

Deformation Bands. Bands within individual *cold-worked crystals*. The bands and matrix differ variably in *orientation*. (A. 27.)

Deformation Curve. A curve in which % deformation is plotted against time, under specified conditions.

Deformation Hardness. A measure of the distortion properties of metals.

Deformation Number. (See SACH'S WEDGE DRAWING TEST.)

Deformation Point. (See PYROMETRIC CONE EQUIVALENT.)

Deformation Resistance. The ratio between roll pressure and *contact area* in rolling operations.

Deformed Bar. Steel bar with projections or depressions at regular intervals used for the reinforcement of concrete.

Deforming Groove. The specially formed groove in rolls intended for rolling *deformed bars*.

Deforming Test. A test to ascertain the degree of deformation during heat treatment.

Defrasing. (*Frasing.*) Removing the uneven edges at the end of lengths of cut tube.

Degasifier. An alloy added to molten steel or metal to facilitate, either by chemical or mechanical means, the release of dissolved gases, which otherwise would be entrapped during solidification.

Degras. (*Lanum, Wool Fat.*) A grease used as a lubricant in wire drawing.

Degreasing. Various reagents are available for the removal of grease from the surfaces of metals, among which soda is one of the oldest and best known. More recently, vapour degreasing has come into wide use and for this method of operation, trichlorethylene is a commonly used solvent. Other solvents in use are perchlorethylene and carbon tetra-chloride; these are both more toxic than trichlorethylene. This latter solvent has a vapour density 4·5 times that of air and so can be used in an open tank heated at the bottom and cooled near the top. (See also MASSA DEGREASING.)

Degrees of Freedom. (See PHASE RULE.)

De Lattre Pickling Process. The pickling liquor contains per litre, 1 g.-mol. of ferrous sulphate, ½ g.-mol. of hydrochloric acid and 1 g.-mol. of sulphuric acid. This solution is maintained at a constant temperature of 50° to 55° C. by steam coils, and the ratio of the two acids is maintained during the whole pickling operation by appropriate additions of both acids and the inhibitor which consists of gelatin peptonized by hydrochloric acid. Pickling is carried on until the total ferrous-sulphate concentration reaches 326 to 394 g. per litre, when the solution is passed to the recovery plant. (I. 27a.)

De Lavaud Process. (*Spun Pipes.*) A method for the *centrifugal casting* of pipes. The pipes are cast in a steel cylinder or mould, which revolves in a hollow cylindrical jacket. The space between the outside of the mould and the inside of the jacket is filled with water. The driving mechanism is a *Pelton water wheel*, which is attached to the bell end of the mould. (K. 46.)

Delay Table. A table for holding partially rolled steel until the rolling can be completed.

Deleading. Removal of the lead coating formed on steel during cold drawing through *dies* when lead is used as the lubricant. The removal is usually effected by immersing in acid.

De Leeuw Hardness Tester. In this instrument the specimen under test is placed on a table supported by a hydraulic piston. The piston moves upwards forcing the surface of the specimen against a pointed diamond or a steel ball, according to the hardness of the material under test. (L. 20.)

d'Elhuyar, Fausto. (1755–1832.) A Spanish chemist, who first prepared metallic tungsten.

Deliquescence. The absorption of atmospheric water by a substance and the dissolving of the substance by the water thus absorbed.

Delivery Guide. A device for supporting the rolled steel in the correct position as it emerges from the rolls. (See GUIDE.)

Delta Iron. (δ) The allotropic form of iron existing, in the case of pure iron, between 1405° C. and the melting point 1535° C. It is non-magnetic, and the atoms are arranged in the *body centred cubic structure*, as in *alpha iron*.

Delta Rosette. (See STRAIN ROSETTE ANALYSIS.)

Demagnetization. The process of reducing the magnetism in a magnetized body. This may be achieved by applying a magnetizing force which opposes that producing the original magnetizing force or by exposing the body to an alternating magnetic field which is gradually reduced to zero. A permanent magnet may be demagnetized by heating to a red heat or by rough usage.

Demagnetization Curve. A curve showing the relation between the *magnetic flux density* (B) and the *magnetizing force* (H) for values of the latter decreasing from saturated to zero *induction*.

Demagnetizing Force, H_d. A magnetizing force applied in such a direction as to reduce the *remanent induction* in a magnetized body. (See DEMAGNETIZATION CURVE.) (A. 28.)

Demurrage. (*a*) The rate or amount payable to the ship owner by the charterer for failure to load or discharge ship within agreed time. (*b*) A similar charge made on railway trucks. (*c*) In economics the term refers to the charge made by the Bank of England on exchanging notes or gold for bullion.

Demy. Size of paper 17½ × 22½ in. (printing) or 15½ × 20 in. (writing). (See BOOK SIZES.)

Dendrite. (*Pine* or *Fir Tree Crystals.*) A tree-like formation. Metal crystals grow by branches developing in certain directions from the nuclei. Secondary branches are later thrown out at periodic intervals by the primary ones and in this way a skeleton crystal, or dendrite, is formed. The interstices between the branches are finally filled with solid which in a pure metal is indistinguishable from the skeleton. In many alloys, however, the final structure consists of skeletons of one composition in a matrix of another, giving what is called a *cored structure*. (See also DENDRITIC SEGREGATION.)

Dendritic Powder. (*Arborescent Powder.*) Particles, usually of electrolytic origin, having a typical pine tree structure.

Dendritic Segregation. (*Coring.*) Inequality of composition within the same crystal. This is due to the fact that in the process of the solidification of a solid solution the dendritic axes, being the first to solidify, have a different composition from the interdendritic material. Further, inhomogeneity may be caused by the trapping of metallic or non-metallic constituents in the *dendrites* during the freezing of the metal. Certain elements show this tendency to segregate more than others. The segregation is revealed by the differential attack by etching agents. (N. 19.)

Dendritic Structure. (See DENDRITE.)

Denison Creep Testing Machine. A high-temperature creep testing machine of the vertical type. Mounted on the cast-iron baseplate are four steel columns supporting the weighing system and adjustable rests are provided for supporting the furnace. The top and bottom specimen holders, of heat- and creep-resisting material, are respectively connected to the steelyard and straining screw by means of universal couplings. Four terminals are provided for thermocouple leads, these being mounted on a small panel on the baseplate. A further terminal is provided for earthing. The diameter of the specimen over the effective length is 0·1785 in., and the area 0·025 sq. in. The straining screw is raised and lowered by means of a single bevel reduction gear inside the baseplate, through either of the ball handles which rotate a phosphor bronze nut. Adequate adjustment is provided to cover 1 to 2 in. long specimens. Load can be applied between ½ ton and 30 tons per sq. in. (M. 37.)

Denitriding. The term has been applied to the operation of softening portions of nitrided parts. It is, however, pointed out that it is a misnomer since the nitride needles remain in the grain boundaries of the case. It is supposed that at high temperatures a change in the state of the nitrogen combination may take place resulting in a partial diffusion of the nitrides. By slow cooling, a softening of the case occurs. (A. 55.)

Dennison Method. A method of preparing the surface of shafts and similar objects in which the surface is threaded to hold particles of molten sprayed metal. After cutting, the tops of the threads are knurled to a depth of about 0·015 in. No other treatment is necessary. (D. 17.)

Denseners. Pieces of iron or copper which are so shaped that they can be inserted into a mould to form part of the face. They are placed in the faces of the sand mould where the heaviest sections of metal occur with the object of conducting the heat from these heavy sections, thus promoting uniform cooling throughout the casting.

Densified Wood. Wood impregnated with phenolic resin. It has been used for patterns.

Densitometer. A device used in *spectrographic analysis* for the measurement of the density of the spectrum lines, since the density can be related to the concentration of the element in the sample which is being analysed. The procedure adopted is to pass light from a constant source through the spectrographic plate and on to a photocell in series with a galvanometer. The photocell is situated behind a narrow slit across which an image of the spectrum line can be traversed. This results in a variation of the photo-current according to the density of the line being measured. This is interpreted finally as a deflection reading on the galvanometer scale. (O. 5.)

Density. The mass per unit volume of a substance expressed as grams per cubic centimetre or pounds per cubic foot. If metric units are employed, the density

is numerically identical with the *specific gravity*. In *powder metallurgy, apparent density* is the weight of a unit volume of powder, usually expressed in grams per cubic centimetre under standard conditions of compacting. *Pressed* or *green density* is the weight of a unit volume of an unsintered compact. *Tap density* is the apparent density of a powder obtained when the volume receptacle is tapped during loading. (See also RADIOGRAPHIC DENSITY.)

Density Bottle. A calibrated glass bottle used for determining the density of liquids, and powders.

Density Ratio. The determined density of a green or sintered compact, divided by the absolute density of the material. It is usually expressed as a percentage.

Densograph. (See ELECTRODENSOGRAPH.)

Deoxidant. (See DEOXIDATION.)

Deoxidation. (*Killing.*) The term, as applied to steelmaking, refers to the process of removing oxygen from molten steel by the addition, immediately before casting, of elements, such as aluminium, manganese or silicon, the latter elements usually being in the form of ferro-manganese, spiegeleisen, or ferro-silicon, having a high affinity for oxygen, the resultant oxides passing into the slag. The object in the elimination of the gases is to prevent their evolution during the solidification of the steel, with the formation of *blowholes*. The material added to effect the removal of the oxygen is known as the *deoxidant*, or more generally as the *deoxidizer*. See also RIMMING, and WILD STEEL.

Deoxidizers. (*Scavengers.*) Elements having a high affinity for oxygen which on adding to the molten steel, either in the bath or in the ladle, do not remain in the steel to any appreciable degree but combine with the oxygen and pass into the slag as oxides. It should be noted that in the earlier stages of melting, i.e. the *boil*, the carbon content of the bath acts as a deoxidizer, reducing ferrous oxide to metal, with the evolution of carbon monoxide. (See DEOXIDATION.)

Deoxo Indicator. An instrument which, it is claimed, gives accurate and continuous measurement of small quantities of oxygen or hydrogen in mixtures of these two gases, or separately in other inert gases. It is based on the measurement of the heat of combination of oxygen and hydrogen and employs a precious metal catalyst, similar to that used in the *Deoxo Process*.

Deoxo Process. This process employs a specially prepared catalyst for the removal of oxygen from hydrogen or from inert gases by bringing about the combination of hydrogen and oxygen in stoichiometric proportions. This reaction takes place at room temperature and the resultant water vapour is carried away in the gas stream and can be removed by any conventional dehydration method. (M. 141.)

Department of Scientific and Industrial Research. (See D.S.I.R. HEADQUARTERS TECHNICAL INFORMATION SERVICE.)

Dephosphorization. The elimination of phosphorus from molten steel. (See BASIC BESSEMER, and BASIC OPEN HEARTH PROCESS.)

Depletion. (See IMPOVERISHMENT.)

Depolarization. The reduction of counter-e.m.f. by removing or diminishing the causes of *polarization*. Depolarization is effected by means of a *depolarizer*, which usually takes the form of an oxidizing agent, such as manganese dioxide, which reacts with the hydrogen as it is produced at the positive electrode.

Depolarizer. (See DEPOLARIZATION.)

Deposit Attack. Corrosion occurring underneath or around a non-continuous deposit on a metallic surface.

Deposited Metal. *Filler metal* that has been added to the weld by a fusion-welding process.

Deposited Metal Zone. The portion of a fusion-weld that consists substantially of *deposited metal*.

Deposition Efficiency. The ratio of the weight of metal deposited in *welding* to the net weight of the electrodes consumed. (A. 37.)

Deposition Rate. The weight of metal deposited in *welding* operations in a given unit of time. (A. 37.)

Deposition Sequence. The order in which the increments of *weld metal* are deposited. (See LONGITUDINAL SEQUENCE, and BUILD-UP SEQUENCE.) (A. 37.)

Deposit Sequence. (See DEPOSITION SEQUENCE.)

Depth of Cut. The distance between the work surface and the machined surface measured at right angles to the machined surface.

Depth of Fusion. The distance that fusion extends into the *base metal* from the surface melted during *welding*. (A. 37.)

Derbyshire Spar. (See FLUORSPAR.)

Derustit. An electrochemical process for removing rust and surface deposits from metal. An electric current is passed through an alkaline solution, oxide being removed whilst the sound metal is unaffected.

De-Rusting. A descaling process for steel, cast iron, malleable iron, and other

iron alloys. No acid is required, thereby eliminating subsequent rusting and possible corrosion of surrounding equipment. The parts are immersed in the solution and electrically charged as cathodes for a period varying from a few seconds to several minutes, depending on current density and the condition of the metal. A wide range of current density can be employed, ranging from five to several hundred amps per sq. ft. The bath is controlled by titration. The finished parts are bright and clean.

Descaling. (*a*) In rolling mill practice, the term used for any method applied to remove scale from the steel being rolled. The usual methods are: the blowing of steam under high pressure on to the steel; the throwing of brushwood on to the steel before it enters the mill, *ragging* of the roll passes, and spraying water on to the steel. (*b*) In finishing processes, the removal of *scale* from the surface of steel by mechanical or chemical means, e.g. by *sand-*, or *shot-blasting, tumbling, flame descaling,* or *pickling. Induction heating* has been used to remove surface scale after heat treatment. In this method, the temperature of the scale is raised so rapidly that its sudden expansion causes it to flake away from the underlying and cooler metal. (*c*) The removal of scale from the inner surface of boilers and tubes.

Descloizite. $4(Pb,Zn)O.V_2O_5.H_2O$. A vanadium ore.

Deseaming. The removal of defects from the surfaces of ingots or semi-finished products. This may be done by a *chipping hammer*, or more usually in modern practice by the use of an oxy-gas flame. In cold deseaming, the steel whilst cold is examined for defects such as *seams, rokes, splits, pulls,* etc., and these defects are removed by burning them out with an oxy-acetylene torch, hand operated. In hot deseaming, the steel whilst still in a hot condition passes through an apparatus in which four banks of oxy-acetylene burners effectively remove the skin on all four sides of the steel. (See also SCARFING and WASH HEATING.)

Deshaw Process. A process for rust removal in which the corroded articles are submerged in an alkaline electrolyte of high conductivity, and are then electrolysed cathodically at a current density of either 10 to 40 amp./sq. ft. at 6 volts, or 40 to 125 amp./sq. ft. at 12 volts. The hydrogen produced on the metal surface frees and disperses the rust, and a subsequent period of anodic treatment drives off any included hydrogen. After washing and drying, a thin protective sealing coating is applied which is an excellent base for subsequent painting or enamelling. (P. 45.)

Desiccant. A substance having an affinity for water, e.g. calcium chloride, used for removing moisture from the surrounding air as for example, in a *desiccator*.

Desiccation. The process of drying.

Desiccator. Laboratory apparatus designed to keep residues or specimens free from moisture. It consists of a glass bowl with a closely fitting ground-glass lid, which is rendered air-tight by smearing with vaseline. A well in the bowl is filled with a *desiccant*, the well being covered by a tray of perforated zinc.

Designs. May be protected by registration at the *Patent Office* for five years upon payment of 10 shillings. They may be renewed for two further periods of five years each upon payment of £2 and £5 respectively. A registered design protects an outline, shape or pattern only. Designs may be inspected at the Patent Office.

Desiliconization. (See P. 473.)

Detecting Internal Corrosion. An instrument has been developed for detecting and indicating corrosion pits on the interior surface of gas well pipes. The device to be lowered into the well tubing contains a very small motor which rotates a permanent magnet inside a coil of many turns of fine wire. The magnet and coil are kept in the centre of the tubing and as long as the tube is smooth no voltage is generated in the coil; when they come opposite a pit the effective air gap is increased and the magnetic flux through the coil decreased. The voltage fluctuations are transmitted through wires connected to an amplifier and cathode-ray oscillograph above ground.

Detrex Soniclean Process. A metal cleaning process in which ultrasonic energy is combined with a chlorinated solvent vapour degreasing. The parts are immersed in the cleaning solution which is vibrated by high-frequency sound waves above the audible range. It is claimed that the results are similar to hand wiping because of the direct impact of the solvent on the surface. (K. 10a.)

Detroit Cup Test. A cupping test similar in type to the *Erichsen*. It employs a steel ball as plunger, the depth of cup being shown on a dial gauge.

Detroit Rocking Electric Furnace. A furnace of the indirect arc type, employing both radiation and conduction in the heat transfer, used for the pro-

duction of high-duty grey iron. The furnace consists of a horizontal drum set upon a suitable base with the electrodes entering at the axes. Since it operates single phase, only two electrodes are used. The steel shell is entirely lined with refractory material, and contains only three openings—the two electrode ports, and the charging door. Pouring is done from a spout in the charging door. In operation, the furnace rocks about its approximate horizontal axis, first clockwise, then counter clockwise. The arc of rotation in either direction is limited only by the relationship of the metal line to the door opening.

Deuterium. (*D.*) *Heavy hydrogen.*

De-Vecchis Process. A method for the smelting of *pyrites* which entails the roasting and magnetic concentration of the raw material followed by reduction in a rotary kiln or electric furnace. The product may be briquetted and reduced in the blast furnace, but is better smelted in an electric furnace. In France, the process is of importance in connection with the production of sponge iron which is afterwards worked up into steel in the basic open hearth or electric furnace. (S. 100.)

Development of Inventions Act. The Act, 1948, established the National Research Development Corporation. Its functions are: The development or exploitation of inventions resulting from public research, or any other invention which is not being developed or exploited; and acquiring, holding, disposing, and granting of rights in connection with inventions resulting from public research or other sources.

Devex Process. The production of sulphide precoats for use in extrusion and forming of metals, particularly ferrous metals. They are formed by vapour-phase sulphurization in a controlled atmosphere during annealing, by thermal decomposition of a pre-dipped coating, by the chemical conversion of oxide or scale, or by immersion in a hot aqueous solution. (H. 37.)

Deviation. (*a*) In X-ray metallography, the angle between the direction of incidence produced through the substance, and the direction of diffraction; twice the glancing angle of incidence; usually written 2θ. (*b*) In optics the angle between the incident ray and the emergent ray after passing through a prism.

Devitrification. The formation of crystals in a material formerly in the glassy state, by holding at a temperature below its liquidus.

De Vries Test. (*End-Quenched Bar Test.*) A test to give the relative hardenabilities of deep hardening steels. A 1-in. diam. bar 6 in. long is end-quenched from the austenitizing temperature in a fixture so constructed that the top of the bar is kept at approximately 650° C. during the quench. This makes the temperature in the bar a function of the distance from the quenched end and allows the steel in the bar to transform isothermally at the various temperatures. After the bar has been in the fixture for an hour, it is taken out and given an over-all quench. The austenitic areas in the bar then transform to martensite. The amount of transformation at each temperature is determined by making hardness measurements along the side of the bar and comparing the hardness at each position with the maximum hardness. By comparing the loss in hardness at various points with the temperature at those points during the quench the relative amount of transformation at any temperature can be estimated and thus the relative hardenability of different steels can be determined. (cf. JOMINY TEST.)

Dew Point. The temperature at which condensation of water vapour in the air takes place.

Dewetting. The gathering into globules of a surface coating as, for example, the formation of globules of water on an oily surface.

Dewey Process. A process for tapering or curving seamless or electric welded metal or steel tubes, which allows wall thicknesses to be increased or decreased. It employs a long tube-shaping machine which has a tail stock, travelling carriage bed and a movable head stock. The tube to be tapered is chucked at each end and rotated and the forming proceeds towards the driving end of the machine. Elongation is accommodated by allowing the driving end to float. The tube is held in a bushing in the carriage. On each side of the tube on the carriage there is a free-turning shaping roller which rotates by friction with the tube and spins it down. (J. 7.)

Dextrin. A vegetable gum used as a *core binder.*

De-zincification. Corrosion of an alloy containing zinc (usually brass), involving loss of zinc and a surface residue or deposit of one or more less active components (usually copper). (A. 27.)

d'Huart Reagent. An etching reagent which reveals not only the macrostructure and faults, such as piping, segregation, particularly sulphur and phosphorus, and cracks, but also slip-lines in mild steel which have been

stressed beyond their elastic limit. The composition is as follows: distilled water 100 ml., concentrated hydrochloric acid 100 ml., crystallized chromic acid 40 g., anhydrous nickel chloride 16 g. The reagent is prepared by dissolving the nickel salt in the hydrochloric acid solution with gentle heat. After cooling, the chromic acid is added and the reagent is then ready for use. Its action is very rapid, the duration of attack varying from a few seconds to 1 minute at most, and the solution should be freshly prepared when required. (D. 20.)

Di. An abbreviation for *didymium*.

DI. A French symbol for a type of fracture showing the characteristics of the *D* and the *I* types.

Diagometer. An electroscope, in which a dry pile is employed to measure the amount of electricity transmitted by various bodies, or to determine their conducting powers.

Diagonal Pass. (*Diamond Pass.*) An approximately square pass cut or set diagonally.

Diagonal Rolling. A rolling operation in which there is no lateral spreading, the shaping beginning with the first pass.

Diagram. For X-ray diffraction patterns, a representation, either a photograph as taken or a projection therefrom; e.g. *index diagram*.

Dialysis. A process separating colloids from soluble salts by allowing the latter to diffuse through a semi permeable membrane.

Diamagnetic. Pertaining to bodies which are repelled by a magnet or which tend to set their longest dimension at right angles to the lines of force when placed in a magnetic field.

Diamo-Brinell Hardness Tester. A modification of the *Brinell* machine using a diamond pyramid indenter instead of a ball.

Diamond Cubic. A lattice having two face-centred cubic arrangements of atomic centres, one of which is displaced with respect to the other by a quarter of the diagonal of the unit cube.

Diamond Pass. (See DIAGONAL PASS.)

Diamond Pyramid Hardness Number. (See DIAMOND PYRAMID HARDNESS TEST.)

Diamond Pyramid Hardness Test. An indentation hardness test in which the indenter, a square diamond pyramid with an angle between opposite faces of 136°, is forced under a standard load into the surface of the specimen under test. The hardness is determined by measuring the diagonal of the indentation produced. The *diamond pyramid hardness number* is the quotient of the applied load divided by the pyramidal area of the impression. The number is obtained by dividing the applied load in kilograms by the surface area of the impression in square millimetres computed from the measured diagonal of the impression. It is assumed that the impression is an imprint of the undeformed penetrator.

Dianodic Process. A method for the protection of metals against pitting. It employs a dual treatment of molecularly-dehydrated phosphates and chromates over selective *pH* ranges. It is claimed that its use in relatively low concentrations gives benefits not obtainable with single treatments such as chromates, phosphates, etc., at considerably higher concentrations. (K. 1.)

Diaphanometer. (*a*) An instrument for measuring the transparency of the air. (*b*) An instrument for determining the degree of turbidity and depth of colour of solutions.

Diaspore. A hydrated aluminium oxide, and a constituent of many *bauxites*. It is used for increasing the alumina content of alumino-silicate refractories.

Dia-Testor. (*Wolpert Hardness Tester.*) A hardness testing machine. The instrument is available in three sizes, and makes use of a Brinell ball or Vickers indenter. An image of the impression is projected on to a ground-glass screen at a magnification of 20, 70 or 150 times, and is measured by means of a graduated scale. (W. 36.)

Diathermometer. An instrument designed for examining the thermal resistance or the heat conducting power of objects.

Diatomite. (See INFUSORIAL EARTH.)

Diazo Paper. Photographic material depending on the light sensitivity of certain organic dyes. Development is accomplished by fuming with ammonia or by treating with an alkaline solution.

Dichroloscope. An instrument to exhibit the two complementary colours of polarized light.

Dichroism. Crystals, or salts, exhibiting two colours, due to unequal absorption of light rays by different planes.

Dichromate Treatment. A chemical treatment for magnesium alloys in a boiling sodium dichromate solution, resulting in a surface film that resists corrosion.

Dickenson's Etch. A method of revealing the macrostructure of steel. After a preliminary treatment in 10% nitric acid the specimen is etched with a solution containing 40 g. ferric chloride, 3 g. cupric chloride, 40 ml. hydrochloric acid and 500 ml. water.

Dickenson, John Henry S. (1882–1934.) A British metallurgist; he was a pioneer investigator of the subject of creep.

Dick's Process. An early type of extrusion process in which metals were formed by forcing at an elevated temperature through a die.

Didymium. (*Di.*) A mixture of *praseodymium* and *neodymium.*

Die. (*a*) A metal block used in stamping operations. It is pressed down on to a blank of sheet metal on which the pattern or contour of the die surface is reproduced. (*b*) An internally threaded steel block provided with cutting edges for producing screw threads. More recent usage is to insert Chaser dies in a Landis or Herbert head. (*c*) In *drop forging,* steel blocks usually supplied in pairs with part of the impression in each block, the lower die being attached to the anvil whilst the upper one is attached to the hammer itself, and moves up and down with it. (*d*) In *wire drawing,* a small plate or body containing one or more tapering holes called *die holes.* (*e*) In *punching* or *piercing,* the bottom tool into which the punch is guided giving clearance between punch and die, which results in shearing of the metal. (*f*) In *resistance welding,* a member usually shaped to the work contour to clamp the parts being welded and conduct the welding current. (*g*) A device used in *forge welding,* primarily to form the work while hot and apply the necessary pressure. (*h*) In *powder metallurgy,* the part or parts making up the confining form in which a powder is pressed. The parts of the die may include some or all of the following: *die-body, punches* and *core rods.* (*j*) A tool having a prepared hole through which tubes are pulled in cold drawing.

Die Angles. The angles in a wire drawing die, include the *entrance, approach, reduction, bearing, relief,* and *exit* angles.

Die Approach Angle. The part of the wire drawing die profile between the entrance and the *reduction angle.*

Die Assembly. (See DIE SET.)

Die Barrel. A cylindrical liner for a *die* used in powder metallurgy.

Die Bearing. (*Die Parallel.*) The cylindrical portion of a wire drawing die.

Die Block. A block which is bolted to the bed of a punch press and which holds the die.

Die Body. The fixed part of a *die.*

Die Box. (See DIE HEAD.)

Die Case. In a wire drawing die, the steel or brass blank into which the die insert is pressed.

Die Casting. (*a*) The process of pouring metals into final shapes in metal moulds. If the metal is forced into the mould the process is known as *pressure die casting,* but otherwise it is known as *gravity-* or *permanent-mould die casting.* The process is usually applied to alloys having relatively low melting points, e.g. tin, zinc, lead and copper, aluminium or magnesium base alloys. The advantages of this process are the high precision of the castings so produced and the high rates of production which may be achieved. (*b*) The product of the die casting process.

Die Casting Alloys. Alloys suitable for *die casting.*

Die Cavity. In *powder metallurgy,* the regular or irregular opening of the *die* into which the powder is fed, and in which the powder is compacted. (G. 30.)

Die Chuck. A small two- or three-jaw independent chuck.

Die Entrance. The first part of the die profile having relatively big tolerances.

Die Exit Angle. The back of the wire drawing die from which the wire emerges.

Die Forgings. *Forgings* produced in *dies,* i.e. *drop-* and *upset*-forgings.

Die Head. (*Die Box.*) The holder into which screwing dies are fitted in a screwing machine for the production of screw threads.

Die Hobbing. The production of multiple cavity moulds by *hobbing.* The first essential of the process is a highly polished hardened tool steel *hob,* of the required contour and preferably with a slight taper. The blanks for the impressions are made from annealed mild steel. The hob is allowed to sink slowly into the die blank allowing sufficient time for the metal to flow. The pressure rises to the maximum required for a particular die and then remains fairly constant as the hobbing action progresses. The process is used only when multiple cavities are required in great quantity and where dimensions must be held to close limits. Further, it is used for the manufacture of moulds which would be extremely expensive to machine. (B. 9.)

Die Holes. (See DIE.)

Die Insert. (*a*) A removable liner or part of a die body or punch. (*b*) In a wire drawing die, the cylindrical part consisting of hard metal carbide.

Die Lines. Lines or markings caused on drawn or extruded products by minor imperfections in the surface of the die. (A. 27.)

Die Mark. (See DIE SCRATCH.)

Die Parallel. (See DIE BEARING.)

Die Plates. Plates of steel or iron with tapered holes of several sizes for drawing wire.

Die Radius. The radius on the exposed edge of a deep drawing die.

Die Reduction Angle. That part of the die profile in which the actual reduction of the wire takes place and having close tolerances.

Die Relief. The part of the wire drawing die profile which follows the bearing part. The usual included angle is 10 degrees.

Die Ripping. Regrinding hard metal carbide dies.

Die Scalping. Scraping the surfaces of bar or rod by drawing through a sharp-edged die.

Die Score. (See DIE SCRATCH.)

Die Scratch. An elongated mark on the surface of a drawn product caused by abrasion.

Die Set. (*a*) The parts of a press that hold the *die*, and locate it in proper relation to the punches. (A. 27.) (*b*) In wire drawing, a series of dies presenting diameters of decreasing gradation to meet the specified reduction.

Die Shift. The movement of the dies out of position causing the impressions to be out of alignment.

Die Sinking. Forming or machining a depressed pattern in a *die*. (A. 27.)

Die Stock. A hand screw-cutting tool, consisting of a holder in which screwing dies can be secured; it is held and rotated by a pair of handles.

Die Welding. A *forge welding* process in which the parts to be welded are brought to a suitable temperature and the weld is completed by pressure applied by means of *dies*. (A. 37.)

Dielectric Heating. A method of high frequency heating in which the object to be heated, which must be non-conducting, is placed in a high frequency alternating field where it is heated by the continually reversed polarization of the molecules. It has found application in the foundry for the drying of sand cores. (B. 14.)

Dietert Moisture Teller. An apparatus for the rapid determination of moisture content, which consists of a balance, a drier, which incorporates a small air blower and heating element, and several pans approximately 1 in. deep by 5½ in. diam., the bottoms of which are made of very fine wire mesh, for holding weighed samples of sand.

Dietert Process. A process for the production of precision moulds which involves blowing a contoured core around a pattern to form half of a mould. The equipment required is a core blower, a pattern mounted on a blow plate, a contour drier, a core oven, and some means of clamping the half-moulds together during pouring. The oil binder used in the sand must be carefully selected, but otherwise the sand is normal core sand. The pattern fits into the drier and leaves a space of the required thickness into which the core sand is blown through holes round the outside edge of the pattern. After drying, the half-moulds are ready to be clamped together for pouring.

Dietert Tester. An apparatus for the direct reading of a Brinell hardness after impression without the aid of magnification or conversion tables. After the impression is made, the reading is taken by pressing gently against the part so that the depth pin guides itself into the centre of the impression. Brinell hardness is read directly from the dial. The needle can be put back to zero by means of an exterior control if it becomes bent after long usage or when it has been subjected to shock.

Diescher Elongator. (See DIESCHER MILL.)

Diescher Mill. (*Diescher Elongator.*) A mill for the production of seamless tubes, in which a pierced blank enters on a freely floating *mandrel* on which it is cross-rolled while the mandrel moves in the forward direction. Cross-rolling is inherently an expanding process, because the contact area between the roll and blank is long in the direction of tube travel and short in the direction of roll travel. If cross-rolling only were applied on a floating mandrel, a tube with uncontrolled expansion and of much larger diameter than that of the pierced shell would be formed, but in the Diescher mill this expansion is prevented by the elongator discs, which, by frictional contact with the blank, not only prevent uncontrolled expansion, but also pull the blank forward and convert the expanding tendency of the cross-rolls into elongation of the tube. (T. 47.)

Differential Aeration Cell. (See AERATION CELL.)

Differential Flotation. A process of *flotation* which permits different metallic sulphides to be separated from each other as well as from the *gangue* of the ore.

Differential Gear. A gear permitting relative rotation of two shafts driven by a third. The driving shaft rotates a cage carrying planetary bevel wheels meshing with two bevel wheels on the driven shafts. The latter are independent, but the sum of their rotation rates is constant.

Differential Hardening. (See DIFFERENTIAL QUENCHING.)

Differential Heating. A method of heating in which the temperature is so controlled that a desired non-uniform distribution of temperature is attained throughout the object being heated.

Thus, on cooling, the physical properties vary as required in the different portions of the same body.

Differential Permeability. The ratio of a small change in the *magnetic flux density* in a magnetic material to the change in the magnetizing force producing it.

Differential Quenching. A quenching process by which only certain desired portions of the object are quenched and hardened. (A. 28.)

Differential Quench Method of Determining Austenitic Grain Size. For this method a gradient quench is employed, in which, the heated piece for a portion of its length, is immersed in water and therefore fully hardened, the remainder of the piece projecting above the quenching bath being, therefore, not hardened. In this method there will be a small transition zone, not quite fully hardened. In this zone, the former austenite grains will consist of martensite grains outlined by small amounts of fine pearlite (nodular troostite), thus revealing the austenite grain size. For etching, 2% solution of nitric acid in ethyl alcohol is used. (M. 14.)

Differential Thermal Analysis. A method of analysing clays and certain minerals. Originally, the temperature of the specimen was measured relative to that of an adjacent inert material. Thermocouples embedded in the test and inert materials were connected in opposition, so that any appreciable e.m.f. set up during the heating resulted from the evolution or absorption of heat in the test sample. In the modern methods small test samples (e.g. 0·4 g.) are employed and are packed, side by side, with the reference material (usually recrystallized Al_2O_3) in a metal block. The block is placed in an electric furnace equipped with automatic controls to obtain a constant rate of temperature rise. Both the temperature of the block, and the temperature difference between the test and reference materials, are recorded automatically; tests run to 1000° C. usually take about 1 to 1½ hours to complete. To obtain satisfactory reproducibility of results the experimental conditions need strict standardization. (G. 55a.)

Diffraction. The spreading of light waves when passing the edge of an object. This is observable when the source of light is small. At the edge of the shadow and parallel to it, a few alternately light and dark bands are seen which are called *diffraction fringes.* Diffraction observations established the wave theory of light.

Diffraction Fringes. (See DIFFRACTION.)

Diffraction Grating. A device for the measurement of light waves.

Diffraction Pattern. In X-ray metallography, the totality of the intersections, with a plane or other surface, of the beams diffracted by a crystal or by a crystalline aggregate. (A. 27.)

Diffubrite Process. A chromium diffusion process developed for use with conventional furnace equipment, a special sealing device preventing any possible contact between the work and the furnace atmosphere. Articles to be treated are packed, with a chromizing compound, into boxes, and sealed with a silicate compound which prevents any permeation of the furnace atmosphere into the box. On removal of the charge from the furnace, the molten silicate solidifies and has sufficient strength to maintain the seal, despite contraction of the gases within the container, but can be readily broken when required. The chromizing compound employed has an average composition of 60% of ferrochromium powder, 0·2% of ammonium iodide, and the remainder unvitrified kaolin. This compound, when heated, generates a reducing atmosphere, consisting of a mixture of hydrogen and nitrogen, within the box, and liberates chromium iodide which reacts with the surfaces of the workpiece. (M. 49.)

Diffusion. The process whereby the molecules in a solution move from the regions of high concentration towards regions of low concentration until complete homogeneity is attained. This process is rapid in gases, and moderate in liquids, whilst the migration of atoms within a solid is brought about by thermal activation. Examples of this include *nitriding*, *case hardening* and *cementation* which involve diffusion into the surface of a solid whilst *decarburization* involves diffusion from the surface.

Diffusion Coefficient. A factor of proportionality representing the amount of substance in grams diffusing in one second across an area of one square centimetre through a unit concentration gradient. (A. 27.)

Diffusion Column. An instrument for the determination of the specific gravity of mineral particles.

Diffusion Layer. A term used in electrolysis to denote that portion of the electrolyte surrounding the electrodes in which the concentration changes.

Diffusion Zone. The zone, in a *cladded* product, between coating and *core*, in which diffusion between the two has occurred.

Diffusionometer. An instrument to ascertain the rate at which diffusion of gases takes place.

Digofat. A bath consisting of manganese phosphate used for the phosphatizing of iron and steel surfaces.

Dikrom Process. A method of chromizing in which the ferrous articles to be treated are first thoroughly cleaned and then packed in a special cement contained in a chest which can be securely sealed. The whole is then heated at 1050° to 1100° C. for 6 to 8 hours and allowed to cool in air. It is claimed that this treatment produces no significant dimensional changes; the thickness of the effective diffusion layer varies between 0·02 to 0·15 mm., depending upon the hardness of the basis steel and the processing temperature, and that good wear-, heat- (not more than 850° C.) and corrosion-resistant properties are produced. (R. 19.)

Dilastrain Method. (*Rosenholtz-Smith Apparatus.*) A rapid method of determining the endurance limit. It requires the selection of identical specimens of the material which are subjected to a definite range of stress, and then put through an equal number of cycles of vibration so that all will be on an even level of fatigue. Test pieces which are then placed in the apparatus and subjected to controlled temperatures ranging from 20° C. to 100° C. have an initial length of 2 in. As temperature is stepped up each specimen changes in length in proportion to the amount of stress to which it has been previously subjected. The apparatus automatically magnifies the amount of each expansion 3500 times and records it. In approximately two hours the total linear expansion of all test specimens has been recorded. When these values are plotted against the stresses previously applied to the specimens, it is found that a sharp dip in the resulting curve appears at the point where the test material reaches its endurance limit. (W. 33.)

Dilatometer. An instrument for measuring expansion or contraction caused in a metal by changes of temperature or structure. It may be used for determining the *transformation temperatures* of different steels by measuring the volume changes which take place on heating and cooling. On heating regular expansion occurs until the *alpha iron* changes to the *gamma* form, when there is a sudden and marked contraction; on further heating, the gamma iron expands regularly. On cooling, the phenomenon is reversed.

Dilatometric Test. A test used to measure the change in length or volume occurring when a steel sample is heated or cooled. The method may be applied for the determination of the *critical points* in steel.

Dilution. (*a*) Further addition of water or other solvent to a solution. (*b*) The reciprocal of concentration; the volume of solvent in which unit quantity of solute is dissolved. (*c*) A term used to describe the mixing of the deposited electrode metal with that part of the base steel which is molten during the welding operation. The resulting weld metal, therefore, is a mixture of electrode metal and base steel.

Dilution Law. (See OSTWALD'S DILUTION LAW.)

Dilution Ratio. The volume of the diluent divided by the volume of the solvent.

Dimensional Stability Tests. A section of annealed steel is machined to ¾ in. in diam. by 3 in. to 5 in. long. After machining, the specimen is stress relieved by heating to a temperature just below the *transformation range*, and cooling slowly. The specimen is then ground and measured for length and diameter. A standard uniform heat treatment is used and care taken to avoid scaling. The dimensions may be rechecked before and after tempering if desired. (A. 27.)

Dimethyl Glyoxime. A reagent used in analytical chemistry for the determination of nickel.

Dimorphic. (See DIMORPHISM.)

Dimorphism. The condition of having two different forms, e.g. substances which may exist in either of two distinct crystal systems are said to be *dimorphic.*

Dimorphous. (See POLYMORPHISM.)

Dimple. (See DIMPLING.)

Dimpling. (*a*) The operation of producing dents on the surface of metal sheet in order to permit the use of rivets or bolts having countersunk heads; no metal is removed in the process. (*b*) Removing a surface defect (U.S.A.). (*c*) In engineering, a slight conical depression produced by a twist drill after a small initial feed into the work; used as a guide for further drilling.

D.I.N. Deutsche Industrie Normen. German Standard Specifications. Copies are available at the British Standards Institution.

D.I.N. Slag Test. A German standard test for the resistance of refractories to attack by slags at high temperatures. (D. 19.)

Dinas Rock. A highly siliceous mineral used in the production of refractory bricks.

Dings. Kinks in the surface of a sheet.

Dip. (*a*) The angle at which a layer of rock is tilted from the horizontal. (*b*) A bath of molten metal or chemical solu-

tion which reacts on the surface of a metal article when it is immersed therein.

Dip Brazing. A *brazing* process in which the heat is obtained from a bath of molten metal or salt, the alloy usually being preplaced in the joint. In *metal bath dip brazing* the filler metal may or may not comprise the bath and is generally used for small work, *salt bath dip brazing* being used for larger work. (C. 15.)

Dip Calorizing. (See CALORIZING.)

Dip Soldering. Dip soldering comprises the immersion of the article in a bath of molten solder. The method is usually applied to the joining of thin sheet metal where clearances are small and where large fillets are not required, as for example, copper radiators. The size of the bath is determined by the size of the articles, the depth they are submerged and the amount of heat abstracted by the article. Automatic means of replenishing the solder can be used. Solder baths are equipped with temperature controls. Operation of the process of fluxing and dipping can be manual or continuous. Special precautions are necessary to maintain the parts in contact until the solder solidifies. A modification of dip soldering is used in sealing the side seams of cans. The seam is coated with solder on passing over a roller revolving in a solder bath. (M. 9.)

Dipping. The term is employed in relation to various processes where a brief immersion in a liquid is involved, e.g. as in the coating of metal by immersing it in molten metal, paint or lacquer; or in *pickling* by immersion in an acid solution.

Direct Arc Furnace. (See HÉROULT ELECTRIC ARC FURNACE.)

Direct Casting. *Teeming* from the *ladle* into the *ingot mould* without the use of a *tundish*.

Direct Current. (*D.C.*) (*Continuous Current.*) An electric current flowing in a circuit without change of direction round the circuit.

Direct Fired Furnace. A furnace in which the fuel is burnt within the heating chamber so that the material being heated is in direct contact with the products of combustion.

Direct Oxidation. The introduction of oxygen gas directly into the steel bath in the hearth of an open hearth or electric furnace.

Direct Process. The production of iron or steel direct from the ore as distinct from the usual process in which pig iron is first produced and then purified to make iron or steel.

Direct Process Print. A print made on dye-sensitized paper generally used as a *shop print*, e.g. *Diazo Paper*.

Direct Quenching. Quenching carburized parts directly from the carburizing operation.

Direct Rate Curve. A cooling curve in which the temperature forms the ordinate and time the abscissa. This type of curve is used in the thermal analysis of alloys.

Direct Reading Spectrograph. (See SPECTROGRAPHIC ANALYSIS.)

Directional Properties. The variation of mechanical properties, as for example, in the longitudinal as compared with the transverse direction, in the same piece of steel. This variation is caused by deformation effected in one direction, as for example, in *rolling*.

Directional Solidification. The fundamental basis of sound castings, in that the metal in the mould should commence freezing at points farthest from the feeding heads, and that in order to prevent *bridging*, solidification should proceed continuously towards the feeder heads which should be the last to solidify. (R. 47.)

Dirty Casting. A casting containing an excessive amount of *non-metallic inclusions* in the body of the metal.

Dirty Steel. Steel containing an excessive amount of *non-metallic inclusions*.

Disa-Electropol. A compact apparatus measuring 17¼ in. wide × 12½ in. deep × 16 in. high, for the rapid production of microsections. It is possible to complete the entire polishing cycle from the moment a specimen has been prepared by grinding a flat surface on it, until the polish is complete, including after-etching, washing in alcohol, and drying, in approximately three minutes. (M. 104.)

Disappearing Filament Pyrometer. An instrument in which the hot body is viewed through an eyepiece and the current passing through a lamp is adjusted by means of a rheostat until the tip of the filament is of the same brightness as the hot body. The temperature of the hot body is then read off from an ammeter, on which the scale is calibrated in degrees of temperature.

Disarrayed Metal. Metal having a deformed lattice.

Disc Depression Weld. A *disc weld* where the discs between the parts are inserted in prepared recesses in one or both parts. (B. 105.)

Disc Process. A method employed in Germany, for the atomization of metal powders. Molten metal, such as steel, cast iron, copper, brass, and bronze, is poured in a thin stream from a *tundish*

and passes vertically downwards through an annular jet, from which issues water directed downwards at high pressure. The metal is broken into globules which are then rapidly swept out of the atomizing zone by knife blades set in a horizontal disc rotating at a very high speed. The globules of metal are in a plastic state when struck by the blades and the final metal particles are irregular and flattened. (M. 142.)

Disc Weld. A weld where the overlapping parts are joined by the resistance spot welding of discs inserted between the parts. (B. 105.)

Discard. (*Crop.*) The portion of an ingot cropped off to remove the *pipe*. Discard always refers to the top portion of the ingot unless otherwise specified.

Discrete. Remaining separate. The term is used in connection with particles which may remain isolated or distinct.

Discontinuity. A defect in a metal, such as a crack, cavity or inclusion.

Dished Plate. A plate forged or pressed into a dish-like shape in order to increase its stiffness when subjected to pressure on the convex side.

Dishing. (*Coining.*) (*a*) Forming a cup or depression. (*b*) The curvature of the *web* in the tyre of a railway coach.

Disintegration. Reduction of massive material to powder. (A. 27.)

Disintegration Test. (See HATFIELD INTERCRYSTALLINE CORROSION TEST.)

Dislocations. Postulated vacant atom sites in metal crystals. These vacant sites may move under stress or alloy concentration gradients and such movements are employed to explain plastic deformation, creep, diffusion and other phenomena. (A. 27.)

Dislozierte Reflection. The reflection of light from etched metal surfaces.

Dispersed Phase. The phase which is distributed through the *continuous phase* or matrix. It may occur either in granular or lamellar form. An example of the latter is found in *hypo-eutectoid steels* where *pearlite* (iron carbide) is seen against a background of *ferrite*, the *continuous phase*. The dispersed phase can be considerably modified by heat treatment.

Dispersion. (*Deflocculation.*) The separation or scattering of fine particles in a liquid medium. The term is often used in connection with the fineness test for clay.

Dispersion Hardening. (See AGEING.)

Dispersoid. Finely divided particles of a relatively insoluble constituent, apparent in the microstructure of certain alloys. (A. 27.)

Displacement Series. Synonymous with *electrochemical series*.

Disruptive Strength. The maximum strength of a metal when subjected to three principal tensile stresses at right angles to one another and of equal magnitude. (A. 27.)

Dissimilar Metal Weldment. A weld metal which differs appreciably in composition from that of at least one of the materials on which it is to be deposited. When a dissimilar metal weld is produced, the resulting mixing of fusion is generally referred to as *dilution* because the alloy content of a more highly alloyed material, generally the weld metal, is decreased by being mixed with a metallic composition of lower alloy content, generally the base metal. (T. 13.)

Dissociation. The reversible or temporary breaking down of a molecule into simpler molecules or atoms, e.g. *ionization*.

Dissolved Carbon. Carbon in solution in steel, in either the liquid or solid state.

Distillate. Liquid obtained by a condensation of the vapour, in *distillation*.

Distillation. Process of converting a liquid into vapour, condensing the vapour, and collecting the condensed liquid or *distillate*. Used for separating mixtures of liquids of different boiling points or for separating a pure liquid from a non-volatile constituent.

Distribond. A siliceous clay containing *bentonite*, used as a bond in moulding sands.

Distribution. The variation or uniformity in particle size of sand.

Disturbed Metal. The *cold worked* metal formed on a polished surface during the processes of grinding and polishing.

Ditch Structure. (See ELECTROLYTIC OXALIC ACID ETCH.)

Dithionate Process. A process for extracting manganese from low-grade oxide ores. The manganese ore is leached with dilute sulphur dioxide gas in the presence of calcium dithionate solution, the manganese being recovered from solution by precipitation with slaked lime and then nodulized or sintered. (R. 4.)

Divalent. Having a *valence* of two, i.e. capable of combining with two atoms of hydrogen or their equivalent.

Dividers Method. (See YIELD POINT.)

Divorced Pearlite. (*Granular Pearlite, Spheroidite, Spheroidized Cementite.*) *Pearlite* in which the *cementite* has been spheroidized by prolonged annealing just below the Ac_1 point, or by annealing at the same temperature after cold working. The cementite lamellae ball up into rounded globules and so lose their strengthening effect on the ferrite; steel so treated becomes softer and more ductile.

DMPA. Defence Materials Procurement Agency. (U.S.A.)

DMVr (Austrian) Test. This is a modification of the *Mesnager* test in which all the conditions are the same, but the depth of the notch is increased to 3 mm. (B. 74.)

D.O. Defence Order (U.S.A.).

Dobie. A roughly formed brick for grinding into *grog*.

Doctor. In electroplating, a device consisting of an anode of the metal to be deposited, covered with a fabric or sponge saturated with the plating solution. It is applied to the article to be plated, which is made the cathode.

Doctoring. The local deposition of metal on imperfectly plated parts.

Dogger. An assistant operator at a draw bench, the man in charge being known as the *drawer*.

Doghouse. A structure of basic or silica brick covered with chrome ore sometimes provided to cover the fuel ports on furnaces fired with fuels other than *producer gas*.

Dog Leg. (*a*) Strip bent first in one direction and then in another. (*b*) A permanent kink in a wire rope.

Dogs. The two jaw-like claws of a crane which grip the ingot when it is either being charged into, or drawn from, the *soaking pit*.

Dog's Ears. (*a*) A name given in *butt welding* to the small triangles of angle bar, shaped like a dog's ears, which are tack welded at the end of the joint in order to prevent the weld metal running out when welding continuously without descaling between passes. (*b*) A term used in the U.S.A. for a defect on the surface of a rolled product caused by a splash of metal on the mould wall during teeming, which has become oxidized and stuck to the surface of the ingot.

Dolomite. The double carbonate of calcium and magnesium which, when calcined, is used as a basic refractory for the linings of basic furnaces.

Dolomite Limestone. *Limestone* with an appreciable content of magnesium carbonate and hence intermediate between normal limestone and *dolomite*.

Domain Theory. According to this theory, a ferromagnetic material is composed of small regions, or domains, each magnetized to saturation. The directions of magnetization, however, differ from domain to domain so that the net magnetization is zero when no external field is applied. The effect of the applied field is to change the direction of magnetization in the separate domains, and the body as a whole becomes magnetized. (B. 77.)

Doppel-Duro Process. A method used for the surface hardening of crankshafts, in which the shaft is rotated very slowly in a lathe, the journal being heated during rotation by an oxy-acetylene flame, and subsequently quenched by a water jet situated below the flame. The width of burner and water jet is equal to that of the journal. The advantages claimed for this method are, reduced costs, simplicity of operation and uniform hardness.

Doppler Effect. A shift of a spectral line which depends on the *Doppler Principle*, which states that whenever there is relative motion between the source of a wave motion and a receiver, the apparent frequency at the receiver differs from the frequency of the source. Hence light emitted by an atom that is moving rapidly towards the *spectrograph* slit will appear on the film as a slightly higher frequency, i.e. shorter wave-length, than a normal line emitted by an atom moving in a vertical or transverse direction. Atoms moving away from the slit will be recorded at slightly longer wave-lengths. Hence as there are many degrees of motion of emitting atoms, the lines are broadened.

Doppler Principle. (See DOPPLER EFFECT.)

Dornin Process. This process consists of two parts, i.e. making the ingot and isolating the segregated zone so that it can be cropped with a minimum loss of steel. Neither part has any value without the other. Standard killed steel melting practice is used. Steel is poured into a *big-end-up mould* of very heavy taper, about two to three times that normally used on *hot-top ingots*, and immediately covered with insulation. The ingot solidifies completely in the mould and is then stripped and sent to the pits or furnaces, where it is heated and soaked exactly as it would be for rolling or forging. The processing is done under a press or presses. The heated ingot is first placed in a cast-iron holding die and positioned under a press. A hollow, tapered punch is then driven into the top of the ingot to the bottom of the segregate, the bottom of the punch being protected by a heat-resistant weld deposit. The next step is to drive the steel surrounding the segregate down past the bottom of the segregate which is thus isolated. The punched-out core is cropped at this point, all the steel remaining in the ingot being sound and usable save for a layer amounting to 1% to 2%, that represents the original top surface of the ingot as poured. The punched-out core weighs about 1% of the ingot's weight. (D. 43.)

Dosemeter. An instrument for measuring the quantity of radiation or dosage. It may be carried, as a safety precaution, by a person coming in contact with hazardous radiations (e.g. X-, alpha-, beta-, and gamma-rays). (T. 32.)

Dosimeter. (See DOSEMETER.)

Dot-Weld. A process for welding cast iron and repairing defective castings by filling in surface blemishes, pin- and sand-holes, etc. The *Mogul Quench Arc Weld Machine*, a high-amperage, low-voltage unit operating on alternating current, is connected to the electrode holder, the *Dot-Weld Pistol*. The electrode is automatically fed to the work by means of a finger trigger friction drive residing in the pistol handle. Incorporated in the pistol is an air cylinder which vibrates the electrode, thus making and breaking the arc, and resulting in the rapid application to the work of a large number of small dots of fused metal. (M. 126.)

Dot-Weld Pistol. (See DOT-WELD.)

Double Angle Tuyere. A type of *tuyere* which, by means of vanes set in the nose, imparts a twist of 90° to the blast. It is claimed that by the use of this type of *tuyere*, the blast penetrates farther into the furnace and as a result, more coke is burnt with the same amount of *blast*. (S. 98.)

Double Annealing. The process as applied to *hypo-eutectoid* steel consists of heating to above the upper *critical point* and holding at that temperature until complete solution of the carbide has been achieved, using the lowest possible temperature to secure minimum *grain size*, cooling slowly to just below the lower critical point, reheating to just above the lower critical point and holding to dissolve any pearlite that may have been formed, followed by very slow cooling. (P. 3.)

Double Bar and Yoke Method. In electrical engineering, a ballistic method of magnetic testing, in which two test specimens are arranged parallel to each other and clamped to yokes at the ends to form a closed magnetic circuit. A correction for the effect of the yoke is made by altering their position on the bars, and repeating the test.

Double Belgian Mill. (*Boecker's Wire Mill.*) A combination of continuous *rolling* and *looping mills* using a series of stands of rolls, e.g. seven or nine, six or eight of which, respectively, are arranged in two parallel trains, each of three or four stands, so that the corresponding stands in each line are opposite each other with three or four continuous groups of two stands each. Power is transmitted to the rolls from a central shaft through three sets of gears thus regulating the speed and rotation of the rolls in each stand so that a rod can be looped by catches from one stand to the other right up to the finishing stand.

Double Converted Bar. (See CEMENTATION.)

Double Cut. (See CUT.)

Double Current Furnace. A special form of electric furnace in which direct current is used for an electrolytic process and alternating current for heating, on the principle of the *induction furnace*.

Double Deck Blocks. (See BULL BLOCK.)

Double-Dip Hot Galvanizing Process. In this process the articles, after removal from the galvanizing bath and while the excess zinc is dripping off them, are sprayed with finely powdered ammonium chloride and re-dipped into the molten zinc. In this way rough places and inclusions of dirt, oxides, etc., in the first coat are completely removed, and a thin, bright, non-porous zinc coating, highly resistant to corrosion, is obtained. (I. 3.)

Double Double. In *pack rolling*, a pack consisting of two sets of four sheets.

Double Duo Mill. (See ROLLING MILLS.)

Double Faggotted Iron. Wrought iron which has been twice worked through the reheating furnace and rolls.

Double Impression Method. A method of making an approximate determination of the Brinell hardness of metals. It consists of placing a hardened steel ball between the material to be tested and a specimen of known hardness and pressing them in a simple arbor press or a vice. No measurement of the force exerted is required. The impressions on both materials are measured under a lens or microscope and from these and the hardness of the comparison specimen, the hardness of the material can be calculated. (M. 27.)

Double Piercing Process. A method for the manufacture of seamless tubes in which the steel billet is first pierced to a comparatively heavy wall thickness, and then, without intermediate reheating, undergoes a second piercing operation which reduces the wall thickness and correspondingly increases the length and diameter of the product.

Double Refined Iron. Iron to be classed as double refined shall be all new *wrought iron*, which shall be first rolled into *muck bars*. These bars shall then be twice piled and rerolled. All iron shall be free from steel and from foreign scrap. The manufacturer may use his own mill products of at least equal quality, but only in the first

piling. In the final piling all bars shall be of the full length of the *pile*. (A. 28.)

Double Salts. A compound of two normal salts, i.e. a crystal formed when solutions of two different salts are mixed in equivalent proportions and then evaporated.

Double Shear Steel. (See CEMENTATION.)

Double Skin. (*Bottom Splash, Ingot Shell, Plaster.*) A defect consisting of a secondary layer of steel sometimes found on the surface of top poured mild steel ingots. It is suggested that two factors may be responsible for the origination of the defect, (i) trapping of deoxidation slag near the ingot surface during solidification, and (ii) splash moving forward from the mould wall and allowing liquid steel to flow behind it. The former factor gives a double skin effect not visible on the surface, and the latter a visible double skin or *curtaining*. (W. 5.)

Double Tempering. A retempering or second tempering operation sometimes necessary for steel containing retained austenite, which breaks down during cooling from the first tempering operation to form new and hence untempered martensite. (See SECONDARY HARDENING.)

Double Treated. A term sometimes applied in the U.S.A. to steels which have been quenched and tempered as distinct from those which are merely oil quenched without subsequent tempering.

Doubler. The press or power hammer with a long flat face, used for flattening the curve in the pack in *doubling*.

Doubles. Thin steel sheets produced by folding over the original sheets (*doubling*) and reducing the cross-sectional area by hot rolling.

Doublet. In X-ray analysis, a pair of lines from the same element that differ little in wave-length. (A. 27.)

Doubling. A process in the manufacture of tinplate, in which after the original bar has been hot rolled in the sheet mill for a number of passes, the sheet is doubled, reheated and the doubled sheet is again hot rolled, the process of doubling being repeated until the sheet has been reduced to the desired thickness.

Doubling Floor. The space between the reheating furnace and the roll stand.

Downcomer. An alternative name in the U.S.A. for the *downtake*.

Downhand Weld. (*Underhand Weld.*) A weld made in a surface lying horizontally or at an angle not more than 45° to the horizontal, the weld being made from the upper or top side of the parts jointed.

Downtake. (See BLAST FURNACE.)

Dozzle. A refractory *feeder head*, raised to white heat and inserted in the top of a crucible steel ingot mould. It is filled with molten steel which flows downwards to fill up the cavity formed by the contraction of the solidifying ingot.

D.P.A. Defense Production Administration. (U.S.A.)

DPG-Schleuder Process. A method of producing iron powder in which molten iron or steel, of the appropriate composition, heated in the high-frequency furnace or Bessemer converter to 100° to 150° C. above its melting point, is poured in a thin, dropping stream on to a centrifugal machine. The stream passes over a conical hydraulic jacket and is thus cooled and divided up into drops, which are again further dispersed while still in the plastic state by a disc, fitted with impact devices and rotating at high speed, being finally solidified in water. (B. 47.)

D.P.H. Diamond Pyramid Hardness.

D.P.N. Diamond Pyramid Hardness Number.

Draft. (*Draught.*) (*a*) (*Leave*). The amount of taper in the side walls of *die* impressions, to facilitate removal of the forging from the die. (*b*) The taper given to the sides of a *pattern* to enable it to be withdrawn easily from the *mould*. (U.S.A.) (*c*) In bar rolling, the difference in sectional area between a pass and the bar which enters that pass and is actually expressed as a percentage of the entering bar. (*d*) In wire drawing, the percentage reduction in area of a wire on being drawn through a *die*. (*e*) Reduction in the wall thickness of a tube during cold drawing.

Draft Angle. The taper of the *draft*, expressed in degrees.

Drag. (*Nowel.*) The lower half of a sand mould.

Drag-Out. The liquid which adheres to material during removal from a process tank, e.g. pickling, and which is therefore wasted.

Drag-Out Contamination. A term usually applied to high-temperature melting chloride salt carried over with the work when removing it from the *austenitizing* bath and plunging it into the quenching bath. This high-temperature salt precipitates in the low-temperature bath, caking on the sides and bottom of the quench pot or floating on the molten bath. Preferably it is eliminated by a salt extracting apparatus, otherwise it has to be removed manually. (A. 4.)

Drag Over Mill. (See ROLLING MILL.)

Drainage. Conduction of current (positive electricity) from an underground metallic structure by means of a metallic conductor. *Forced Drainage.* Drainage applied to underground metallic structures by means of an applied e.m.f. or sacrificial anode. *Natural Drainage.* Drainage from an underground structure to a more negative (more anodic) structure.

Draught. (*a*) (See DRAFT). (*b*) The flow of air through a furnace.

Draw. (*a*) A term sometimes used in the U.S.A. for *tempering.* (*b*) To remove pattern from *mould.* (*c*) (*Sink*) An external contraction effect analogous to *piping*, which is sometimes seen on the surface of a casting. (*d*) A form of porosity due to insufficient *venting* at the corners of castings. (See also SHRINKAGE CAVITIES and DRAWING.)

Draw Bar. A bar used for lifting the pattern from the sand of the mould. (A. 26.)

Draw Nail. (*Draw Spike.*) A pointed steel rod which is driven into the *pattern* and acts as a handle in lifting it out of the sand in the *mould.*

Draw Peg. A wooden peg used in drawing the pattern from the *mould.*

Draw Plate. (*Flatter.*) A metal plate pierced with small holes, through which *wire* is drawn during its manufacture.

Draw Screw. A screwed rod with an eye at one end which is screwed into a *pattern* to enable it to be drawn from the *mould.*

Draw Spike. (See DRAW NAIL.)

Draw Widening Test. (See SIEBEL AND POMP.)

Drawback. (*a*) The term applied in foundry work to a body of sand that forms part of the *mould* and which must be drawn back horizontally before the *pattern* can be removed. The drawback is afterwards replaced to preserve the contour of the pattern. Drawbacks are used principally for heavy castings. (*b*) Rebate of import duty of goods which are re-exported. The goods must be in the same state as when imported and unused. For particulars see Notice No. 217, issued by the Commissioners of Customs and Excise, King's Beam House, Mark Lane, London, E.C.3.

Drawbench. A bench on which is mounted apparatus for the cold-drawing of bars, rods, wires, tubes, or other sections, through dies. With wires a number of successive dies may be mounted on one bench, the speeds of the intermediate pulleys being compensated to allow for the increased length of the wire.

Drawer. The operator in charge of a drawbench.

Drawhole. An obsolete term for the *pipe* in a steel ingot.

Drawing. (*a*) Drawing out metal rods into wire, in the cold state, by pulling through a series of consecutively smaller holes (*dies*) in steel plates (*draw plates*). (See also DEEP DRAWING.) (*b*) In U.S.A. synonymous with *tempering.* (*c*) In the solidification of castings, the production of shrinkage cavities by reason of improper design, insufficient feeding, too low a casting temperature. (*d*) Forging to produce the greatest movement in the longitudinal direction. (*e*) In hollow forging, the operation of increasing the length of the forging by working on a mandrel under a forging press in order to obtain the desired wall thickness.

Drawing Compounds. Lubricants employed to facilitate the forming of metals, and to prevent overheating. They include colloidal graphite, oils, soaps and tallow.

Drawing Dies. *Dies* used in drawing operations.

Drawing Down. Forging a bar with the object of reducing the diameter and increasing its length.

Drawing Machine. Apparatus for withdrawing metal from a reheating or treatment furnace.

Drawing the Mould. The operation of lifting a *pattern* out of the sand of a finished *mould.*

Dreibrite. A process for removing scale and oxide from steel. The metal parts to be cleaned are subjected to scouring, the medium employed being steel grit or shot carried in suspension in low pressure air. (I. 48.)

Dreigas. A mixture of producer gas, blast furnace gas, and coke oven gas, i.e. drei (three gases), used in Germany, for the firing of open hearth furnaces. (W. 38.)

Dressed Weld. A weld where the appearance of the exposed surface is improved by mechanical or thermal means.

Dresser. (*a*) An iron block used in forging bent work on an anvil. (*b*) A mallet used for shaping sheet metal. (*c*) A tool for trueing the surfaces of abrasive wheels.

Dressing. (*a*) The sorting and cleaning of ores prior to reduction. (*b*) The preparation of the surfaces of an ingot mould prior to teeming. (*c*) The removal of surface defects by *fettling* or *deseaming.* (*d*) Controlling the *cast* of coiled wire. (*e*) Re-machining the surface of a worn roll.

Dressing Off. (See FETTLING.)

Dressler Muffle Furnace. A furnace for enamelling sheets and cast iron in which the burning air-gas mixture passes along the sides of the muffle in

large Λ-shaped passages, and returns along the hearth in similar but smaller channels; the heat radiating surface is large in proportion to the dimensions of the muffle. (S. 161.)

Drift. A tapered steel bar used (i) for drawing rivet holes into line, (ii) for expanding tubes.

Drift Test. (*a*) A workshop method of determining the ductility of steel plate by boring a hole of a given diameter near the edge of the plate and increasing the diameter by means of a conical tool until a predetermined diameter is obtained or until cracking occurs. (*b*) A test for tubes, sometimes known as the *turn-pin test*. In its usual application the drift is of conical form but there is a similar test in which the drifting consists of opening out the end of the tube so that the expanded portion is parallel to the original tube wall but is of larger diameter.

Drifting. The operation of enlarging a hole by forcing through it a conical tool.

Drill. A revolving tool for making cylindrical holes in metal. It is provided with cutting edges at one end and is fluted for the release of chips.

Drill Feed. The distance travelled by the drill in the direction of its axis during penetration. It can be stated in two ways: (i) inches per minute, (ii) feed per revolution in inches.

Drill Pipe. Tubes used to form the stem of cutting tools for the rotary drilling of bore holes.

Drill Speed. The distance in feet travelled by the outer corners of the drill in one minute; the peripheral speed is usually stated in feet per minute.

Drilling. The operation of making a hole in metal by means of a *drill*.

Drip Edge. The trailing edge of the plate on its passage through the molten tin or terne mixture, carrying a slight surplus of the coating metal.

Drip Melting. A method useful for melting and alloying without contamination. The process consists of feeding a vertical bar of material to be melted into an induction coil in such a way that the end is melted off continuously and the drops are collected below in a mould. The *auto crucible method* consists of holding a pancake-shaped induction coil near the flat surface of a horizontal block of the metal to be melted. With this arrangement, the eddy currents are most intense directly under the coil and hence the liquid is pushed towards the centre where it builds up in a mound. (M. 63.)

Drip Test. A test for determining the corrosive action of coolants for lathes and machine tools. For this test a block is made from metal similar to that used for lathe beds and a number of recesses are formed in it with a milling cutter; small piles of brass and steel chips are put in each recess to simulate workshop conditions; samples of the coolants to be tested are placed in beakers and allowed to drip very slowly over the chips, one coolant to each recess. The test is usually run for three or four days, after which the degree of corrosion in each recess is examined. (L. 39.)

Drive Pipe. Screwed and socketed tubes, in which the ends butt in the middle of the socket; used for well boring operations where heavy percussion loads must be endured.

Drooping Characteristic Welding Source. A source of electric supply in which voltage automatically droops from striking voltage to arc voltage as the load is applied.

Drop. A defect in a casting due to a portion of the sand dropping from the *cope* or other overhanging section. (A. 26.)

Drop Ball. A heavy weight dropped from a height to break up heavy scrap.

Drop Bottom Furnace. (See CUPOLA.)

Drop Core. A type of *core* used in forming comparatively small openings either above or below the *parting*. The seat portion is so shaped that the core is easily dropped into place.

Drop Forging. (*a*) A forging operation in which a metal shape is formed by repeated blows from a drop or steam hammer on to a bar or billet placed between a pair of dies. The upper die containing half the impression of the desired shape is fixed in the tup whilst the lower die, containing the other half of the impression, is in the stationary anvil. The force exerted by the hammer causes *plastic flow* in the metal which imparts a tough fibrous structure to the steel, the die being designed to ensure the most advantageous plastic flow of the material so that the grain follows the contour of the forging with as little interruption as possible. The process is economical only when a large number of reproductions are required as the cutting of the dies is expensive. Where a change not only of form but of the section of the material takes place, the product is a *drop forging*; if only a change of form occurs the product is a *drop stamping*. (*b*) The metal shape made by the drop forging process. In such forgings the *grain flow* or *fibre* is of importance. (G. 50.)

Drop Gate. A term used in the *foundry* for a *pouring gate* or *runner* leading

directly into the top of the *mould*.

Drop Hammer. A forging machine that employs the impact resulting from the action of gravity, with or without added steam or air pressure, on a falling ram. (A. 27.)

Drop of the Beam. (See YIELD POINT.)

Drop Stamping. (See DROP FORGING.)

Drop Test. A strength test for steel tyres which consists of dropping the tyre on to a rail from a specified height (dependent on the tyre diameter), or alternatively, of dropping a heavy weight on to the tyre held in an upright position.

Drop Weight Test. A *U.S. Naval Research Laboratory* test for the measurement of notch ductility in *nodular irons* in which a sharp notch is produced by the cracking of a brittle weld bead on a specimen large enough to be comparable to a structural or cast part, and the temperature is determined below which small amounts of deformation result in brittle fracture. This temperature is termed the *nil ductility transition temperature*. The specimen is brought to testing temperature and is placed weld downwards across supports, a 60-lb. weight being then dropped from a height of 8 ft. and causing the specimen to bend at the centre. Deformation is limited by a stop to 5°; the brittle weld cracks at about 3°, so creating an extremely sharp notch in the specimen. It is claimed that the test determines whether the small deformation associated with the additional 2° of bending after the crack forms suffices to cause fracture of the specimen. Studies on many steels and nodular irons have shown that the change from high notch ductility to nil notch ductility occurs sharply, i.e. over a range of about 10° C. (P. 15a.)

Dropping Bottle. A small bottle having usually a ground-glass stopper in which is cut a narrow channel. The bottle neck, in which this stopper fits tightly, has a similar channel, so that the stopper can be rotated until the two channels meet. By this means liquid poured from the bottle and down the channel, drop by drop, can be readily controlled.

Dross. Metal oxides in or on molten metal.

Dry Analysis. A term now frequently applied to *spectrographic analysis*.

Dry Blast. Air blast for the blast furnace conditioned to contain a minimum of water vapour. The use of this air-conditioned blast appears to be largely discontinued.

Dry Bond Strength. (See DRY STRENGTH.)

Dry Bulb Temperature. The temperature of the surrounding air as indicated on an ordinary mercury thermometer. (Cf. WET BULB TEMPERATURE.)

Dry Chemistry. Chemical reactions induced by heat.

Dry Compression Strength (of Sand). The maximum pressure recorded in pounds per square inch when a steadily increasing compressive force is applied to a test piece prepared in a standard manner, to standard dimensions, dried for a specified length of time at a defined temperature and allowed to cool before testing. The test piece on removal from the drying oven should be placed in a desiccator and allowed to cool to room temperature before being tested. For routine control purposes, test pieces may be allowed to cool in air, provided that they are tested when slightly warm and that occasional checking tests are made using the standard procedure. (I. 15.)

Dry Cyaniding. A development of the *gas carburizing* process, in which both carbon and nitrogen diffuse into the surface of the work from a mixture of ammonia and hydrocarbon gases whose flow through the furnace is counter to that of the work. In continuous gas carburizing, the treatment can be effected first in a high temperature zone at the work entering end of the furnace, the nitriding being permitted to continue in a subsequent zone of lower temperature. In this way, a wide variety of case structures of various hardnesses can be obtained under well-controlled conditions. (C. 54.)

Dry Fineness. The fineness of a sample of foundry sand from which the clay has not been removed and which has been dried at 105° to 110° C. (A. 26.)

Dry Finishing. A process of removing the oil from tin- and terne-plate by passing between *cloth rolls*.

Dry Galvanizing. A process in which the flux solution is spread over the surface of the part to be galvanized and is dried before the part enters the zinc bath. (B. 2.)

Dry Ice. Solid carbon dioxide.

Dry Permeability. The property of a molten mass of sand, dried at 105° to 110° C. and cooled to room temperature, to pass through it gases resulting during the pouring of molten metal into a mould. (A. 26.)

Dry Plate. (*Dry Streak.*) Defective tinplate showing patches of dull surface.

Dry Puddling. A process of *puddling* in which a high grade low silicon pig iron is used. It is carried out on a sand bottom and the decarburization is

effected by air. The metal never passes beyond the pasty stage, i.e. it never becomes molten.

Dry Sand Mould. Moulds which have been baked in an oven at about 200° C. before being put into use.

Dry Streak. (See DRY PLATE.)

Dry Strength. (*Dry Bond Strength.*) The tenacity (compressive shear, tensile or transverse) of a sand mixture which has been dried at 105° to 110° C. and cooled to room temperature. (A. 26.)

Dry Tensile Strength. The strength of a sand after drying at a temperature of about 200° C. It is an alternative to the test for the determination of *dry compression strength* and is applied in particular to sands bonded with organic binders. The tensile test piece is similar to that used for cement testing with a section 1 in. square at the neck, a tolerance of ± $\frac{1}{64}$ in. being allowed. The test piece is prepared by three blows on the standard rammer fitted with a head of suitable shape. A split container is necessary. It is a measure of the resistance to the wash of the molten metal. (I. 15.)

Dry Tinplate. Tinplate having areas deficient in tin.

Drycolene. A protective atmosphere for scale-free hardening, bright annealing, and sintering, which, as it contains carbon monoxide, does not decarburize the surface being treated. The producer for this gas consists of a retort into which charcoal is fed; this retort is heated by coke-oven gas, natural gas, propane or butane, mixed with air, and the products of combustion are passed through the incandescent charcoal, where further reactions take place, producing the "Drycolene". (S. 115.)

D.S.I.R. Department of Scientific and Industrial Research.

D.S.I.R. Headquarters Technical Information Service. Has been merged with the Technical Information and Documents Unit. The new unit retains the name TIDU. Its address is Cunard Building, 15 Regent Street, London, S.W.1 (Telephone: WHItehall 9788). The unit holds the German Industrial Documents which were brought back to this country after the war. It is receiving unpublished reports from British and American sources and it issues summaries of them. Many of these reports contain information which is not published in the normal way. TIDU maintains a technical inquiry service and is the British centre for an international questions and answers scheme. This scheme is organized to provide information about industrial techniques from the U.S.A., Canada, France, Germany, Ireland, Sweden and the United Kingdom.

D.T.D. Directorate of Technical Development (Ministry of Supply Aircraft Production).

Dual Coolant Method. A method of cooling during grinding, developed by *Pahlitzsch*, in which two different cutting fluids are brought separately to the cutting point. Water or a soluble oil emulsion in the usual quantity is supplied externally and tangentially to the wheel, whilst a very small quantity of oil is brought to the wheel bore and penetrates to the periphery, i.e. to the cutting point, through the porous grinding wheel structure. In addition to the combined cooling and lubricating effect, the method offers additional advantages. The grinding wheel pores are kept free from swarf by the centrifugal pressure of the oil, and the formation of oil mist, normally associated with straight oil, is prevented. (P. 1a.)

Dual Structure. (See ELECTROLYTIC OXALIC ACID ETCH.)

Ductile Cast Iron. *Spheroidal Graphite Cast Iron.* (See CAST IRON.)

Ductility. The property of metals which permits deformation to occur without fracture. Ductile metals show considerable elongation under tensile stress and ultimately fail by necking, with consequent rapid increase in stress locally.

Ductilometer Test. A reverse bend test for strip and wire. It differs from conventional tests in the method of bending, the specimen being gripped along its entire length save for a short central portion which is bent freely through a specified angle. The deformed length is approximately equal to 1·5 × diameter, and the number of bends to fracture varies inversely with the angle of bend. The constant of proportionality and the (extrapolated) angle of bend at which the wire does not fail, are indices of the mechanical properties of the wire. (P. 23a.)

Dudley, Dudd. (1599–1684.) Dudd Dudley, the natural son of Edward, fifth Lord of Dudley, claimed to be the first to smelt iron successfully with mineral coal instead of charcoal. In 1621, Lord Dudley, was granted a patent covering a process carried out by his son. (S. 26.)

Dudzeele Process. A method of treating metals intended to be drawn or rolled, in which they are first coated with lead by amalgamating the surface, preferably by treating with a solution of mercury salt and then dipping them into molten lead. A suitable mercury salt solution contains about 50 g. of mercury chloride

in a litre of a dilute solution of hydrochloric acid at 6° Baumé, saturated with ammonium chloride. (D. 47.)

Du-Lite Process. A method for blackening steel surfaces such as rifle barrels or camera parts. The process is one of simple immersion and the coating consists essentially of molybdenum and iron oxides. The corrosion resistance may be enhanced by impregnation with oil or wax.

Dull Rolls. Rolls whose surface has been roughened to a predetermined degree by chemical or mechanical means.

Dulong and Petit's Law. That the specific heat of an element multiplied by its atomic weight is approximately constant and equal to 6·2.

Dumb. (See SAND BUCKLE.)

Dummy. The term as used in the U.S.A. refers to stock that has been given a preliminary rough shaping before being placed between *dies* for *drop forging* complicated shapes.

Dummy Block. The term as used in the U.S.A. refers to a free cylinder that transmits pressure from the ram to the billet or slug in the extrusion of metals.

Dummy Pass. A pass in the roll barrel which plays no active part in the rolling process, i.e. a pass which does no work. Such passes are usually found in three-high mills.

Dummying. The term as used in the U.S.A. refers to the production of the *dummy* for drop forging.

Du Mont Cyclograph. An instrument for measuring and recording changes in magnetic and electrical properties of steel samples under test. It is essentially an extremely sensitive oscillator. The test coil which is placed about the specimen whilst a fatigue test is in progress is part of the oscillating circuit, the readings of the cyclograph being a function of the losses in the specimen.

Dump Test. A test for rivet steel in which short lengths equal to twice their diameter cut from bars shall, when cold, withstand without fracture, being compressed to half their length.

Duo Clad Metals. Clad metals made by the *Armstrong process* in which a composite steel billet is produced by forging or rolling, the bond between the two metals being formed by electrolytic iron deposited on the surface to be welded. (G. 55.)

Duo Mill. A mill used in the manufacture of seamless steel tubes. It consists of a number of stands each containing one pair of rolls. The rolls have a semicircular groove cut in each; the size of these grooves diminishes as the tube passes from one stand to the next and thus gives the required reduction. Successive roll axes are set at 90 degrees in order to roll out any fins which may be formed. The whole series of rolls is driven through gearing from one main motor. (B. 54.)

Duoflex Checker System. A checker arrangement for *hot-blast stoves*. The gas used is only partially cleaned and may contain from 0·5 to 1·5 g. of dust per cubic metre of gas. The top zone of the checkers is formed of straight-walled vertical passages, and the middle zone of vertical passages in each of which two opposite walls are continuously curved and the other two are straight, whilst the bottom zone is formed of vertical passages in each of which all four walls are continuously curved. (I. 47.)

Duovec Method. A magnetic particle testing technique which involves the use of a moving magnetic field which magnetizes the part under test in many directions. Electrical contact heads set up a circular field in the part, and another device, usually a coil, produces a longitudinal field. In order to produce the moving field, the power supply provides two or more different currents simultaneously. The combined currents set up magnetizing forces essentially at right angles to each other and so timed as to produce a moving field in the part. While magnetized, the part is usually sprayed with fluorescent magnetic particles which have been found effective in the location of even the smallest defects. It is then inspected under *black light*. (K. 14.)

Duplex Process. (*Duplexing*.) A term applied to any method of steel production carried out in two stages and involving the use of two different types of melting furnace, e.g. the metal may be blown in a basic *Bessemer converter* and finished in the *basic open hearth*, or *electric furnace*, or it may be melted in an open hearth furnace and transferred to an electric furnace. (D. 48.)

Duplex Spot Weld. A pair of spot welds made simultaneously by the aid of two sets of contact points where two transformers are employed, one at each side of the parts to be welded, the bulk of the current passing in series through the contact points and the two secondaries.

Duplex Structure. A structure consisting of two phases.

Duplex Talbot Process. A combination of the *duplex* and the *Talbot continuous process*. Molten steel from the *Bessemer converter*, already freed of its carbon, silicon and manganese contents, is

charged into the *Talbot furnace*. As this molten steel is poured through the oxidized slag, the phosphorus is removed almost immediately. Sometimes pig iron is poured in afterwards which raises the carbon content of the bath and aids in its deoxidation. A portion of the heat can usually be tapped about an hour after this addition.

Duplexing. (See DUPLEX PROCESS.)

Durability. The term as applied to foundry sand, refers to the rate of deterioration of the sand in use due to the dehydration of its contained clay. (A. 26.)

Duralumin. An aluminium-base alloy containing copper 3·5% to 5·5%, magnesium 0·5% to 0·8%, manganese 0·5% to 0·7%, and silicon up to 0·7%, which can be cast, forged and rolled hot or cold. It is capable of *age-hardening*, e.g. *precipitation hardening* at room temperature, after quenching from about 520° C. but precipitation is more marked and the process is accelerated if ageing is carried out at a temperature of about 150° C., i.e. *artificial ageing*.

Duraspray Process. This consists of applying a priming coat of red lead in oil and while this is still tacky, spraying on zinc dust with dried compressed air. (S. 151.)

Durimet. A low-load hardness tester, which can be used for Vickers-, Knoop-, and Ritz-hardness tests under loads between 15 to 500 g. The speed of load application can be adjusted by using an oil brake. The evaluation is carried out under bright-field illumination at magnifications of 100 or 400 times. The impressions can be measured with an accuracy of 0·000012 in. (or to an estimated value of 0·000004 in.). An outstanding characteristic of the Durimet is the so-called "deformation compensation" which is achieved by spring-loading the probe with three fine steel wires. This deformation compensation gives considerable protection from damage to the probe. Errors which may occur due to one-sided ridging of the impressions are also thereby avoided. When applying the probe to the material under test, a slight bending of the holder (however small) is caused, moving the probe sideways. The compound stage and the arrangement for swinging out the testing attachment enable the examination of difficult cases to be carried out. With the assistance of an attachment mounted on the lens, and in conjunction with a focusing attachment, 35 mm. photographs of the impression can be made.

Durionizing. A process, of electro-depositing hard chromium, on the wearing surfaces of parts as a protection against wear by friction.

Durokawimeter. A magneto-inductive testing instrument for acceptance testing of light alloys, which is claimed to detect faulty heat treatment, cracks in castings and variations in chemical composition. (M. 101.)

Durometer. With this instrument a 10-mm. steel ball is released from an iris diaphragm and drops on to the specimen by gravity. The surface of the specimen is inclined at 45° to the horizontal, and deflects the rebounding ball on to a calibrated horizontal glass plate. The latter carries paper covered with carbon paper so that the rebounding ball marks the distance of rebound, and this represents the hardness. (S. 14.)

Duroscope. An apparatus for the magnetic determination of the durability of steels. (S. 7.)

Durville Rotary Process. A method of casting steel in which the mould is connected to the ladle by means of a trough and in such a manner that the lower edge of the ladle, the base of the trough and the lower side of the mould are in a straight line. These units are attached to a platform which can be rotated in a vertical plane. The apparatus is adjusted so that the ladle is below the mould and the ladle is filled with metal which then flows slowly into the mould when the apparatus is slowly inverted. (N. 20.)

Dusty Tinplate. Tinplate from which the dust from the branning machine has not been completely removed.

DVM Creep Limit. Stress producing a creep rate not exceeding 10^{-4} mm./mm./hour in the 25th to 35th hour.

DVM Test Piece. An impact test piece designed for use at low temperatures. It is 55 mm. × 10 mm. × 10 mm. and carries a rounded notch 3 mm. deep and 2 mm. diameter.

Dwarf Brinell Tester. A portable ball hardness tester in which the load is applied by means of a vice or lever. It carries a special lens for measuring the diameter of the impression and from which the Brinell hardness value can be read directly. (W. 53.)

Dwight-Lloyd Process. A method of sintering fine iron ore and flue dust prior to charging in the blast furnace. (M. 163.)

Dy. Chemical symbol for *dysprosium*.

Dy-Chek Process. (See DYE PENETRANT INSPECTION.)

Dyad Elements. An obsolete term for divalent elements.

Dye Penetrant Inspection. A method for the rapid detection of surface cracks

in engine parts, such as turbine blades, which depends on the fact that some liquids will penetrate into cracks in metals and render them more easily visible. In the *Dy-Chek* process, which is adapted for use on large work, or where single pieces are to be examined, a red dye penetrant is applied to the surface by brush, immersion or spray, and seeps into any cracks or flaws existing. The penetrant contains a solvent dispersable dye, has low surface tension, exceptional wetting ability, good penetration and low viscosity. It is so blended as to be suitable for use at any temperature between −30° F. and +150° F., in order to meet all production line or field inspection requirements. A dye penetrant remover is next applied, this being a solvent with particularly efficient emulsifying qualities, which forms an emulsion with a water rinse, to provide a consistent clean water-break-free surface. Finally, a dye mark developer is applied, again preferably by spraying, to obtain a uniform coating. This developer consists of a suspension of white powder in a volatile solvent, and leaves a matt white layer on the surface. Any surface flaw in which dye penetrant has been entrapped will be shown in a few minutes as a red stain through the white powder coating. *Chek-Spek* involves only two formulae, a dye penetrant and a dye mark developer, but a vapour degreasing plant is used in conjunction with these, both as a precleaner for the removal of normal shop dirt, and as a dye penetrant remover. The penetrant and developer used for this process differ somewhat from those of the Dy-Chek in having higher flash points to suit the warmed surfaces coming from the vapour degreaser. This raised temperature has the advantage of roughly halving the time required for the dye marks to show through the developer. *Met-L-Chek.* A similar process claimed to show up cracks, pores and cold shuts in all types of metal parts. Parts are first swabbed with red dye penetrant. After three minutes the surface dye is washed away with water. The part is then swabbed with white developer which after drying shows up defects as brilliant red lines. *Spotchek* is another dye penetrant of a similar type.

Dynacité Test. (See SCHNADT NOTCH IMPACT TEST.)

Dynactinometer. An instrument for measuring the intensity of the photogenic (light producing) rays and computing the power of object-glasses.

Dynamic Load. An alternating or variable load.

Dynamic Strength. Resistance to impact or vibratory stress. (See IMPACT-, and FATIGUE-TESTS.)

Dynamic Stress. Stress which is suddenly applied and thus tends to produce motion in the part under test, as in the *Izod test.*

Dynamo. An appliance designed to convert mechanical energy into electrical energy.

Dynamo Steel Sheet. Sheet made from steel of low hysteresis loss (e.g. silicon steel), as used in the manufacture of transformers and other electrical machinery.

Dyne. The force required to produce in one second, an acceleration of one centimetre per second in a mass of one gram.

Dysprosium. (*Dy.*) *Atomic weight* 162·46. *Specific gravity* 8·56. A rare earth element.

E

E. Symbol for *Elastic Modulus, Elasticity* and *Damping.*

E and E Magnetic Crack Detector. An apparatus in which the test piece forms the yoke in a closed magnetic circuit energized by means of a specially wound magnetizing coil, there being no current flowing through the part itself. (S. 157.)

Ears. (*a*) The wavy projections formed in deep drawing. These are normally disposed in geometric positions either at 45° or alternatively at 0° and 90° to the direction of rolling. They are caused by the presence of *directional properties* in the sheet due either to the development of *preferred orientation* on annealing or to the *fibrous structure* of the steel. (P. 29.) (*b*) A somewhat similar effect produced in rolling. (See EDGING PASS.) (*c*) The lugs on the *cope* into which the pins of the *drag* fit.

Earth's Crust. The following composition has been estimated:

Elements by weight		*Combined as oxides, etc., by volume*	
Oxygen	47·17		
Silicon	28·00	Silica	59·93
Aluminium	7·84	Alumina	14·97
Iron	4·44	Ferrous Oxide 3.42 } Ferric Oxide 2.58 }	6·00
Calcium	3·42	Lime	4·78
Potassium	2·49	Potash	2·99
Sodium	2·43	Soda	3·40
Magnesium	2·27	Magnesia	3·85
Titanium	0·44	Titanium Oxide	0·74
Hydrogen	0·23	Water	1·94
Carbon	0·19	Carbon Dioxide	0·48
Phosphorus	0·11	Phosphorus Pentoxide	0·26
Sulphur	0·11	Sulphur	0·11
Fluorine	0·10	Fluorine	0·10
Barium	0·09	Barium Oxide	0·11
Manganese	0·08	Manganese Oxide	0·10
Chlorine	0·06	Chlorine	0·06
Strontium	0·03	Strontium Oxide	0·04
Others	0·50	Chromium Oxide	0·05
		Zirconium Oxide	0·03
		Nickel Oxide	0·03
		Vanadium Oxide	0·02
		Lithium Oxide	0·01

Earthy Cobalt Wad. (See BLACK OXIDE OF COBALT.)

Earthy Fracture. A fracture resembling that of hard clay.

Easing. A term used in the foundry for a method adopted to prevent *hot tears*, by removing on solidification of the metal in the mould, any accessible parts of the mould and cores liable to resist contraction.

E.A.W. Electrical Association for Women.

Eberbach Microhardness Tester. The instrument employs a 136° diamond penetrator so mounted that extremely light loads can be applied and small impressions made. The standard instrument includes six calibrated springs capable of applying loads ranging from 7·5 to 550 g. The method is based upon microscopic measurement of plastic deformation. (B. 46.)

Ebonel. A process of surface treatment. It employs a strong sodium hydroxide solution containing an oxidizing agent. It appears that the formation of ferroferric oxide is dependent upon the temperature and partial pressure of oxygen. A strong alkali is required to obtain the necessary temperature and to obtain a solution which has a slow solvent action on iron. The concentration of the solution is 7½ lb. per gallon. It is used at 134° to 139° C. while new and is applied by dipping the article into the bath. After a few square feet of steel per gallon of solution have been treated the range stabilizes itself from 140° to 145° C. Cast iron and steels require treatment with a maximum of 143° C. (L. 48.)

Ebosa Microhardness Tester. This instrument employs a spring-loaded ball or diamond as the indenting tool. (O. 19.)

Ebuliscope. An instrument for observing the boiling point of liquids, especially for determining the alcoholic strength of a mixture by the temperature at which it boils.

Eccentric Coating. An electrode coating that is not exactly the same thickness at all points round the core.

Eccentricity. In a tube, the lack of coincidence of the centre of the bore with that of the outside circumference, resulting in variation of the wall thickness.

Echometer. A graduated scale for measuring the duration of sounds and determining their different values and the relation of their intervals.

Economizer. (*a*) A unit fitted round an electric furnace electrode at the part where it enters the furnace, with the object of decreasing electrode consumption. The economizer is so constructed that the sensible heat of the gases escaping between the electrode and the cooling ring, is removed before coming into contact with the atmosphere. A common type of economizer consists of a water cooled ring provided with suitable expansion chambers for the escaping gases. The effect desired is that the gases shall not ignite when they meet the oxygen of the air, and will thus largely prevent the *chimney effect* with its consequent rapid burning away of the electrodes. Several types of economizer are available. (H. 7.) (*b*) An arrangement of pipes for the pre-heating of boiler feed water by otherwise waste gases.

E.C.P.D. Engineers Council for Professional Development (U.S.A.).

E.C.S.C. European Coal and Steel Community.

E.D.A. Electrical Development Association.

Eddy Current Crack Detection. Essentially this consists of causing an electric current to flow in a metal in such a way that it encounters the suspected crack across its path, so causing a deviation in the flow of current from the inferior conductivity of the defect to the sound material flanking it. This current deviation is then revealed by some device responsive to it, and from this the position of the defect is located. (A. 48.)

Eddy Currents. Electric currents induced in surrounding masses of conducting material by circuits carrying alternating currents.

Eden Foster Repeated Impact Testing Machine. In this machine a hammer of known weight falls freely and vertically from a known height upon the test piece which is rotated through 180° after each blow, the number of blows being automatically recorded until fracture. Various forms of grooved test piece may be used. A special tool is provided for making the grooves in the test piece and means are provided with the outfit for gauging the depth of the groove.

Edge. (*a*) To turn a piece of steel which is being rolled through 90° so that it goes to the mill on its edge. (*b*) To roll a piece which has been so turned.

Edge Condition. (*a*) *Mill Edge.* The normal edge produced in rolling; it does not conform to any definite contour. (*b*) *Sheared Edge.* One that has been cut after rolling. (*c*) *Slit Edge.* The product of strip cut into multiple widths by means of a rotary knife.

Edge Cover Straps. A narrow strip of plate welded to the end of a *butt weld* so as to reinforce the end cross-section.

Edge Finish. A rolled edge on strip metal.

Edge Joint. A joint where the component parts are in contact, an edge of each part is in the same plane, and the weld lies across the edges.

Edge Preparation. The contour prepared on the edge of a member for welding. (A. 37.)

Edger. The portion of a *die* used for preliminary forging that distributes the metal in the general proportions of the shape to be forged. (A. 27.)

Edging. In *die forging*, the gathering of the stock at certain points by the *edger* in order to proportion stock to fit the dies.

Edging Mill. A rolling mill in which the rolls are set vertically in a housing for the purpose of rolling the edges of the piece.

Edging Pass. A vertical *pass*, i.e. the application of rolls to the edges of a rectangular section, such as plate, given during or at the end of *rolling* to ensure correct width and to prevent the production of *ears*.

Edging Rolls. Vertical rolls which control the width of the rolled piece.

Edgwick Visual Hardness Tester. A machine in which the image of the Vickers or Brinell indentations made can be projected on to a screen and measured by means of a micrometer slide, without moving either the part tested or the microscope. This is achieved by carrying the indenting point in a hollow cone which also houses the objective of the microscope; after the indentation has been made, the indenter swings aside to expose the objective for projection. The loading speed and duration are controlled hydraulically, and the pressure range allows testing of small components without damage. Measurement of the indentation is facilitated by the projection magnification of x 70 and the graduations on the screen of tenths and hundredths of a millimetre, while a micrometer device reads down to thousandths. The scale screen is rotatably mounted so that the two diagonals of a Vickers diamond impression may be measured. Maximum load capacity is 187·5 kg. (A. 15.)

Edison Gauge. (See CIRCULAR MIL GAUGE.)

EFCO - Olivotto High - Temperature Furnace. An electric furnace which is claimed to be efficient for operations at temperatures up to 1500° C. The principle of the furnace design is the radiation of heat emitted from a bath of molten glass reflected from the roof arch of the furnace on to the work to be heated. The molten glass is contained in channels on either side of the working hearth and electric current is transmitted to it by means of *graphite electrodes* which are immersed in the glass, thus avoiding oxidation. In this way, electrodes have a long life and will run for several weeks without adjustment, the consumption of graphite being low. Thus, a fixed type of electrode can be used, simplifying the construction of the furnace. By means of suitable water cooling, a ring of solid glass forms a gas-tight seal round the electrodes. The electrode lengths are screwed together in the usual way, using nipples, and a simple screw adjustment is available for inserting the electrodes farther into the bath on the infrequent occasions that this becomes necessary. Before doing so, the water supply to the coolers is turned off, allowing the glass seal to melt, facilitating the movement of the electrodes, after which the water is turned on again to freeze the glass, thereby sealing the aperture. The molten glass can be drained off from a stopcock in the bottom of the bath and the broken glass replaced when the furnace is to be relighted. (I. 64.)

EFCO-Virgo Process. A descaling process which depends on the chemical and physical modifications of the scale by the action of the molten salts at a temperature of 480° to 540° C. The scale is then removed in the following stages of the process which consist of a cold-water quench followed by a short immersion in warm dilute acid when necessary. The salt used consists of caustic soda containing active ingredients which chemically convert the refractory oxide to one of a flocculent nature and capable of solution in a weak acid. (M. 153.)

Effective Length of Weld. The length of weld throughout which the correctly proportioned cross-section exists. (A. 37.)

Effervescing Steel. A steel in which a rapid gas evolution occurs in the early stages of solidification, the outer layers of the ingots being relatively pure and usually containing a well-defined system of parallel blowholes; the interior of the ingots is relatively impure and contains scattered *blowholes*. *Pipe* or *shrinkage cavity* is very slight or is absent altogether. Effervescing steels are described as *rising*, *rimming*, *capped*, or *cooler-plated*, according to the state of oxidation of the steel and to the extent to which the effervescing action is allowed to proceed.

Efflorescence. The property possessed by certain crystals of giving up their water of crystallization to the air. (Cf. HYGROSCOPIC.)

Effusion. That property of gases which allows them to pass through porous bodies, i.e. the flow of gases through larger holes than those to which *diffusion* is strictly applicable. (See GRAHAM'S LAW.)

Egg Sleeker. (*Egg Smoother.*) A tool used for producing a smooth surface on a mould.

Egg Smoother. (See EGG SLEEKER.)

Eggertz Test. (*Colour Carbon.*) A rapid method for the determination of carbon in plain *carbon steels*, in which a pre-determined weight of the sample is dissolved in nitric acid and transferred to a graduated tube, where its colour is matched with that of a sample of known carbon content treated in a precisely similar manner.

Ehrhardt Process. A method of producing seamless steel tubes, which is particularly suitable for large and heavy tubes. It is a modification of the *push bench process* in so far as a hot hollow bloom is forced through a series of dies of gradually decreasing bore but in the Ehrhardt process only three or four dies are employed.

EHV Welding. (*Elin-Hafergut Verfahren.*) (See FIRECRACKER WELDING.)

Eikonometer. An optical apparatus for determining the magnifying power of a microscope or for the measurement of microscopic objects. The image is brought to a focus on a micrometer scale which is examined by a magnifier.

E.I.S. Electric Induction Steel.

Ekko Process. A particular application of *electroforming* in which a coating of iron up to ½ in. thick is electrolytically deposited on a pattern. If the surface is made conductive by dusting with powdered graphite, then wood, glass, plastics or similar materials can be used as patterns; metals can also be used, with the exception of zinc and aluminium. On completion of the plating process, the pattern is removed, leaving a cavity which is an exact reproduction of the pattern. (I. 27.)

Elastic Aftereffect. A slight contraction which occurs slowly while metal is standing with no load, subsequent to plastic tensile flow and immediate elastic recovery. *Microscopic stresses*, acting in compression, are responsible for this as well as for the *Bauschinger Effect.* (A. 27.)

Elastic Body. One in which for a given strain there is always induced a definite stress, the stress and strain being independent of the duration of the external force causing them and disappearing when such a force is removed. A body in which the strain does not disappear when the force is removed is said to have a *permanent set* and such a body is called a *plastic body.* (A. 45.)

Elastic Constants. In the general form of *Hooke's Law* the elastic moduli, which vary in individual crystals with the direction of test. (A. 27.)

Elastic Deformation. (See DEFORMATION.)

Elastic Failure. The permanent distortion of a piece to a degree which prevents it from functioning properly. The bending of the frame or the front axle of a motor-car is an example.

Elastic Fatigue. The temporary loss of perfect elasticity shown by certain materials, which having been subjected to deforming stress for long periods do not immediately return to their original form on the removal of the stress, but slowly recover their elasticity.

Elastic Hysteresis. (See DAMPING.)

Elastic Limit. The highest stress that can be applied to a metal without producing a measurable amount of plastic (i.e. permanent) deformation. Usually assumed to coincide with the *limit of proportionality.*

Elastic Modulus. (*E.*) The ratio, within the limit of elasticity, of the stress to the corresponding *strain.* For stresses in tension and compression it is called *Young's Modulus*, for stresses involving change of shape with no change in volume it is called *Shear Modulus*, or *Modulus of Rigidity* and for stresses involving change of volume without change of shape, *Bulk Modulus.*

Elastic Range. (See RANGE OF PROPORTIONALITY.)

Elastic Ratio. The ratio of the *yield point* to the *tensile strength.*

Elastic Stiffness. Resistance to deformation within the elastic range.

Elastic Strain. (See STRAIN.)

Elasticity. The tendency of a body to return to its original size and shape, after having been stretched, compressed or deformed. The ratio of the stress called into play in the body by the action of the deforming forces to the strain or change in dimensions or shape is called the *coefficient* or *modulus of elasticity.*

Elasticometer. A machine for testing both tension and compression springs, in which automatic load indication is made by means of a pendulum. It is built in two load ranges, namely 0 to 500 lb. and 0 to 750 lb. (I. 50.)

Elastrodurometer. A hardness testing instrument in which the height of the rebound of a ball dropped from a specified height on to the polished surface of the specimen under test is taken as a measure of the hardness.

Elcometer. A pocket tool for measuring the thickness of non-magnetic coatings on steel. It consists of two pole pieces connected to two permanent magnets between which is a moving iron. As the pole pieces are placed on different samples, the iron adopts different positions according to the thickness of the non-magnetic coating, this movement being indicated by a needle passing over a graduated scale.

Eldred's Wire. Wire made with a nickel steel core, covered with copper and an outer jacket of platinum or fused platinum borate. It can be sealed into glass and thus finds application in the electric lamp industry.

Electric Arc Furnace. (See HEROULT ELECTRIC ARC FURNACE.)

Electric Arc Stud Welding. A semi-automatic shielded arc-welding process for end welding studs, which consists of developing heat by drawing an arc between the stud (electrode) and the plate (work) to which it is to be welded, and bringing the two pieces into intimate contact when the proper welding temperature is reached. (See also NELSON STUD-WELDING PISTOL.) (S. 73.)

Electric Brazing. A *brazing* process in which the heat is obtained from an electric current. (See ARC BRAZING, RESISTANCE BRAZING and INDUCTION BRAZING.) (C. 15.)

Electric Cleaner. A solution for the cleansing of metal surfaces in which the action is accelerated by the use of an electric current. Such solutions are usually alkaline.

Electric Eye. (*a*) An electronically controlled device which automatically follows the contour of a black-and-white drawing or silhouette. (*b*) A photo electric instrument for automatic temperature control.

Electric Furnace. A furnace whose heat is derived from electricity. The electric furnaces in most common use in steelworks are the *Heroult Electric Arc Furnace*, and the *High Frequency Induction Furnace*, but the term includes other types of steelmaking furnaces such as the *Greaves-Etchell's*, heat treatment furnaces, and for example, small resistance furnaces, used in the laboratory.

Electric Furnace Brazing. This process consists of assembling the clean, scale-free parts, placing the brazing alloy on or near the joints and heating the whole in an electric furnace within which a reducing or inert atmosphere is prevalent. For copper brazing and many other alloys, fluxes are not necessary. The protective atmosphere prevents oxidation and reduces oxides that are present on the surface of the steel. The alloy then becomes so fluid that it is drawn into the joint by capillarity. The furnaces may be divided into two types —continuous and semi-continuous—the former being used for a constant flow of relatively small parts, the latter for intermittent working or components too large for the former. (H. 35a.)

Electric Gauge. An instrument developed for measuring the bores of small guns or tubes of about ½-in. inside diam. Its operation depends on the mutual inductance of two coils. It has a solenoid mounted on each prong of a fork, and the current induced in the secondary varies inversely with the distance between the primary and secondary coils. The gauge is calibrated with rings of known diameter, and the diameter of the tube or gun bore is read directly on the dial of the instrument. (B. 86.)

Electric Hot Top. (See KELLOG ELECTRIC HOT TOP.)

Electric Hygro-Cel. An instrument developed for testing the dryness of foundry sands. It consists of an electric sensing element mounted in a housing. This element is highly sensitive to moisture and responds instantly to minute changes. Any change in relative humidity changes its electrical resistance. The resistance changes are transmitted to the indicator in terms of electrical current and are visually shown by the small portable instrument called an indicator. (H. 1.)

Electric Ingot Process. A continuous method of melting and casting metal with progressive solidification. The molten metal is completely protected from the atmosphere. There is minimum segregation, and as no refractory linings are used there is no contamination. Sound ingots with high yield and no pipe are produced, and as the method possesses extreme flexibility it is possible to make small as well as relatively large ingots. One of the basic raw materials is strip, supplied in coils, which is passed through tube-forming machinery where it is formed into a cylindrical electrode with edges butted. After passing through the contact shoe, where it picks up the current used for melting, the tubular electrode extends into the mould, and the current discharge takes place below a slag blanket. The alloy materials are added to the melt by metering each alloy through a separate metering device. With the metering devices, driven by the same motor that drives the tube-forming machinery, the rate of alloy addition is synchronized with the rate of elec-

trode consumption. Alloying materials are obtained in a free-flowing crushed condition and flow from the storage hoppers through a hopper, into the centre of the tubular electrode, directly through the current discharge, where they are liquefied, and into the super-heated bath of molten metal below the molten flux blanket, and then progressively solidified without being exposed to the atmosphere. Whilst the electric ingot process is a truly continuous melting and casting method, it is not being actually operated in that manner. Present practice is to melt ingots of required length, which eliminates all cutting and which produces literally pipeless ingots. (H. 74.)

Electric Metallic Tubing. (*E.M.T.*) This is made from strip steel which is electrically welded and is usually furnished in electrogalvanized finish with an enamelled interior. (E. 16.)

Electric Pig Iron Furnace. The furnace utilizes electrical heating in the form of an arc for providing and maintaining the required reaction temperature for the charge—a function performed by coke in the normal blast furnace. This type of furnace is economical only where electricity is cheap and plentiful. (W. 47.)

Electric Resistance Butt Welded Tube. Tube produced from steel strip which is formed into the desired diameter and welded by passing a heavy current across the longitudinal joint.

Electric Resistance Welding. (See RESISTANCE WELDING.)

Electric Sheet. A thin magnetic material of such composition and so processed as to be suitable for the construction of laminated magnetic cores. (A. 28.)

Electric Spark Discharge Cutting. (See ELECTRIC SPARK MACHINING.)

Electric Spark Machining. (*Electric Spark Discharge Cutting.*) A method used for the machining of extremely hard alloys. For the drilling of a hole in a metal component, for example, the component is connected to the positive pole of a direct current source, while the drilling electrode is connected to the negative pole. The electrode periodically contacts the component and causes the condenser to discharge. The discharge takes the form of a spark at the point of contact, which becomes quenched by a liquid covering the component. Every spark discharge removes some of the material of the component and the electrode thus drills the hole. To be able to make consecutive contacts, the electrode is moved in the direction of drilling. The success of this process depends on the quenching operation, which should not permit the formation of an arc between the component and the electrode. (K. 42.)

Electric Spark Toughening. A Russian method which is claimed to increase tool life, by making the tool the cathode, and a suitable material the anode, in a spark system at a maximum working voltage of 50. A certain quantity of the anode material, governed by a modification of Faraday's law, is deposited on and in the tool. Of the anode materials tested, greatest increases in durability were obtained with anodes of ferro-chromium (70% Cr.), various hard alloys, or white iron (2·86% C., 1·0% Si). The effect was very marked when tool and anode were thinly coated with a plastic material.

Electric Steel. Steel made by one of the electric processes where the heat required for melting the steel is provided by an electric arc made to pass between the metal itself and a carbon electrode, i.e. the *Arc Process* or by eddy currents induced by a *high frequency* current. In both processes the furnace lining may be either acid or basic.

Electric Strain Gauge. An electrical instrument for the measurement of strain and, hence, of the corresponding stress.

Electric Tropenas Furnace. An adaptation of the *Tropenas furnace* which is particularly suitable for the manufacture of high-alloy iron or steel. The furnace is rectangular instead of circular in section, and additional heat can be supplied by electrical equipment to raise the temperature after the addition of the alloys. To do this a section of the furnace on the tuyere side is removed and a replica section carrying the electrodes is lowered into position and the arcs adjusted, the operation occupying a few minutes only. On completion of the heating, the electrical portion is removed, the solid section replaced, and the charge can then be poured. For adding the alloying materials there is a sealed hopper attached to the tuyere box; this contains one or more partitions. Granulated ferro-silicon, manganese, nickel or chromium may be fed into the bath during blowing operations by means of tubes leading into the tuyere orifices. (I. 53.)

Electric Upset Forging. A method of *upsetting* in which bar stock is slowly upset between anvil electrodes, the necessary heat being supplied by passage of electric current from one anvil to the other through the portion of bar being upset. The great advantage is that the bar stock can be automatically moulded

progressively through the clamping anvil, and a large upset portion, up to 30 times the bar diameter, can thus be produced. The exact amount of material necessary to fill a subsequent drop-forging die impression can thus be obtained in one operation. (G. 41.)

Electric Welding. (See ARC WELDING, and RESISTANCE WELDING.)

Electrical Conductivity. The measure of the ability of a material to pass an electric current. The reciprocal of *electrical resistivity*. The current flowing through a conductor of 1 sq. cm. cross-section under a potential gradient of 1 volt per cm.

Electrical Hot-Riveting. In this process, the two parts to be joined are accurately located and drilled and a flat-headed rivet is pushed through the hole. The rivet is then placed between the electrodes of the machine, under moderate mechanical pressure, and current is applied. When the rivet is sufficiently plastic the current is cut off and simultaneously a much higher forging pressure is exerted, to form the rivet head. It is claimed that this method avoids the work-hardening associated with the cold-riveting of stainless steel; the contraction during cooling ensures a tight rivet, and the grain flow obtained gives a strong rivet head. (L. 6.)

Electrical Machining. (See ELECTRO-MACHINING.)

Electrical Properties. Such properties as *electrical conductivity*, or *specific resistivity*.

Electrical Resistance. Resistance to the flow of electricity. It is the value of the potential difference at the ends of a conductor to the current flowing through it.

Electrical Resistivity. (See SPECIFIC RESISTANCE.)

Electrical Sheet or Strip. A thin magnetic material of such composition and so processed as to be suitable for the construction of laminated magnetic cores. (See ELECTRICAL STEELS.) (A. 28.)

Electrical Steels. Carbon free steels containing up to about 4% silicon used in sheet form for the production of transformers, generators and other electrical plant. (Cf. ELECTRIC STEEL.)

Electrically Excited Resonant-Type Fatigue Testing Machine. A fatigue testing machine controlled by simple electrical circuits. The loads are applied by inertia forces from two heavy masses between which is suspended the test specimen. The system operates as a tuning fork which subjects the specimen to vibratory bending stresses. The amplitude can readily be controlled. (D. 40.)

Electroanalysis. A method of analysis in which the metal to be determined is deposited electrolytically on a previously weighed electrode. On completion of the deposition the electrode is reweighed and the amount of metal present in solution is calculated from the gain in weight.

Electroarcing Process. (See ELECTRO-MACHINING)

Electrobrightening. (See ANODIC TREATMENT.)

Electrocast Process. A method of producing refractory materials in the desired form by mixing the raw materials in the requisite proportions, heating to fusion in an electric furnace, and casting.

Electrochemical Action. (See ELECTROCHEMICAL CORROSION.)

Electrochemical Cleaning. A method for removing weld discoloration from stainless steel; it is particularly useful where access by ordinary methods is difficult. A copper rod is bent to a convenient shape, and tipped with short pieces of rubber tubing, to facilitate handling and to prevent the copper from touching the stainless steel, which would cause short-circuiting. A small amount of 50% phosphoric acid is poured over the specimen, using just enough acid to contact the copper rod and wet the discoloured area. The more concentrated the acid the brighter the finish produced on the steel. The copper rod is connected to the negative terminal of a D.C. power source, the stainless steel part to the positive terminal. The copper rod is then passed, at about 2 ft. per minute, along the joint to be cleaned. Where the weld discolouration extends over a large area, copper strip may be used, wrapped in acid-damped asbestos. (W. 30.)

Electrochemical Corrosion. (*Contact Corrosion, Electrolytic Corrosion.*) Localized corrosion that results from exposure of an assembly of dissimilar metals in contact or coupled with one another, i.e. *electrochemical action*; or of a metal containing macroscopic or microscopic areas dissimilar in composition or structure. The dissimilar elements form short-circuited electrodes, the corrosive medium is the electrolyte, and an electric current is induced, which results in the dissolution of the electrode that has the more anodic solution potential, while the other is unattacked. The same condition may result from local differences within the corroding medium. (A. 27.)

Electrochemical Descaling Process. (See BULLARD-DUNN PROCESS.)

Electrochemical Equivalent. The weight of an element or group of elements oxidized or reduced at one electrode of an electrolytic cell by the passage of a unit quantity of electricity. It is generally expressed in grams per coulomb. (E. 10.)

Electrochemical Jet Test. A method for the determination of thicknesses of metal coatings. A direct current is passed through the stream of liquid flowing through a capillary on to the sample, the latter being made the positive, and the capillary the negative, electrode. At the spot where the jet meets the sample, electrochemical solution of the plated metal takes place. When the base metal is exposed a marked change of current strength takes place, which indicates the end point. (O. 3.)

Electrochemical Series. (*Galvanic Series.*) (*Potential Series.*) A tabular arrangement of the elements in the order of the *electrode potential*, developed when an element is immersed in a solution of normal ionic concentration. The sign is positive for elements whose potentials are cathodic to hydrogen, and negative for those anodic to hydrogen. The order of the elements varies slightly under different conditions of measurement.

Metal at 25° C.	"Normal Electrode Potential" (Potential in salt solution of normal ionic activity relative to the normal hydrogen electrode as arbitrary zero-point) *Volts*	
"*Noble*" or *Cathodic End*		
Gold	+ 1·42	
Platinum	+ 1·2	
Silver	+ 0·7995	
Mercury	+ 0·7986	
Copper	+ 0·3448	
Hydrogen (1 atm)	+ 0·0000	
Lead	− 0·126	
Tin	− 0·136	
Nickel	− 0·250	
Cadmium	− 0·4020	
Iron	− 0·440	
Chromium	− 0·71	Potential almost independent of original concentration of metal ions
Zinc	− 0·7620	
Aluminium	− 1·67	
Magnesium	− 2·34	
Sodium	− 2·712	
Potassium	− 2·922	
Lithium	− 3·02	
"*Base*" or *Anodic End*		

Electrochemistry. A branch of *physical chemistry*, dealing with the inter-relations of electricity and chemistry. The term is commonly used in reference to the chemical phenomena occurring within a liquid through which an electric current is passed and in particular to the activity of the positively or negatively charged ions which carry the current.

Electrocolouring. There are various methods of colouring stainless steel. One method uses a solution of 25 volume per cent sulphuric acid (specific gravity 1·84) with an addition of 8 oz. sodium dichromate per U.S. gallon, with an operating temperature of 70° to 85° C. with anode current density of about 0·6 amp./sq. ft. at 1·0 to 1·3 V. Another method consists of simple immersion of the stainless steel for 5 to 10 minutes in a solution preferably containing 50 volume per cent sulphuric acid (specific gravity 1·84) and about 7 g. of sodium dichromate per litre. (N. 5.)

Electrode. (*a*) A rod of metal, either bare or covered, or of carbon, through which current is conveyed between the electrode holder, and the arc in arc welding or in the electric arc process of melting steel. In *Arc Welding*, the following are the principal types used: (i) *Bare Electrode.* A metal electrode which has neither a flux core nor a flux covering. (ii) *Cored Electrode.* A metal electrode with a core of flux or other material. (iii) *Covered Electrode.* A metal electrode with a flux covering. (iv) *Sheathed Electrode.* A metal electrode with flux surrounding the metal core having a metal sheath. (See also CARBON ELECTRODE, COMPOSITE ELECTRODE, LIGHTLY COATED ELECTRODE, METAL ELECTRODE, and TUNGSTEN ELECTRODE.) (*b*) In *Resistance Welding*, the part or parts of a resistance welding machine through which the welding current and, in most cases, pressure are applied directly to the work. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, chuck or modification thereof. (*c*) The terminals by which a current is led into or out of an *electrolyte*. (A. 37.)

Electrode Efficiency. The ratio between the weight of metal deposited at the cathode, when an electric current is passed through an electrolyte, and the theoretical amount as computed from *Faraday's Law*.

Electrode Force. (*a*) *Dynamic*, in spot, seam and projection welding, the force (pounds) between the *electrodes* during the actual welding cycle. (*b*) *Theoretical*, in spot, seam and projection welding, the force, neglecting friction and inertia, available at the electrodes of a resistance welding machine by virtue of the initial force application and the theoretical mechanical advantage of the system. (*c*) *Static*, in spot, seam and projection welding, the force between the electrodes under welding conditions, but with no current flowing and no movement in the welding machine. (A. 37).

Electrode Holder. A device used for mechanically holding the electrode and conducting current to it. (A. 37.)

Electrode Lead. The electrical conductor between the source of *arc-welding* current and the *electrode holder.* (A. 37.)

Electrode Potential. (*Single Potential.*) The difference of potential between an *electrode* and the electrolyte with which it is in contact. Metals which displace hydrogen from acids, e.g. zinc, are considered to have a less (more negative) potential than noble metals, e.g. gold. (See ELECTROCHEMICAL SERIES.) The American practice is the reverse. (B. 103.)

Electrode Skid. During *spot, seam* or *projection welding,* the sliding of an *electrode* along the surface of the work, i.e. *tip skid.*

Electrode Soldering. In this method, the article is joined to one terminal of a low voltage supply and the soldering tool to the other. Heat is generated whenever the bit makes contact with the work. (M. 9.)

Electrode Tip. That part of an electrode which in resistance welding conducts current to, and exerts pressure on, the parts to be welded.

Electrodensograph. (*Recording Photometer.*) An instrument for the inspection of films. The film is mounted in a carrier, which is moved by a constant-speed electric motor between a source of light and a *photoelectric cell.* The cell is connected to a recording device, and a graph is thus obtained which shows the variations in the current across the cell, which in turn varies with the strength of the light passing the moving film.

Electrodeposition. The deposition of a layer of metal or alloy on to another in an electrolyte consisting of a solution of salts of the metal to be deposited. (See ELECTROPLATING and ELECTRO-TYPING.)

Electrodissolution. Dissolving a substance from an electrode by electrolysis.

Electroerosion. (See ELECTROMACHINING.)

Electroextraction. (*Electrowinning.*) The direct electrolytic recovery of metal from a solution of its salts, the latter usually being obtained by *leaching* ores or residues. (B. 103.)

Electrofacing. The process of coating a metallic surface with a harder metal by electrodeposition to render it more durable.

Electroforging. An operation which employs the electrical output of a resistance welding machine to generate heat in the metal parts and uses the pressure system of the welder to forge or displace the metal as desired. (See OMES ELECTROFORGING PROCESS.)

Electroforming. A process whereby a comparatively thick layer of metal is deposited by electroplating on a mandrel or matrix which can then be removed so that a self-supporting shell or formed article is produced. (N. 12.)

Electrogalvanizing. The electrodeposition of a protective coating of zinc on metal objects.

Electrogranodizing. (See GRANODIZING.)

Electrographic Analysis. The method consists of placing a piece of paper, saturated with a suitable electrolyte, on an aluminium block, pressing the metal specimen under test into intimate contact with the paper, connecting the block and specimen to a direct current supply, thus making the specimen *anodic* so that material from the specimen is dissolved and picked up in the paper which is later washed and developed by suitable reagents. (I. 67.)

Electrographic Contact Print Method. (See CHROMOGRAPHIC CONTACT PRINTING.)

Electrojetal. A companion process to the *Jetal* finish producing a black finish over copper by anodic oxidation. It can be applied to any metal which can be copper plated.

Electroless Plating. A method for plating nickel and cobalt on metal surfaces without the use of electric current. It is effected by chemical reduction of a nickel or cobalt salt with hypophosphite in hot solution. The reaction is catalytic, and under the prescribed conditions of concentration and pH, no plating occurs unless certain metals, such as steel or nickel, are introduced into the bath. (C. 23.)

Electrolimit Gauge. (See FLYING MIKE CONTINUOUS GAUGE.)

Electrolysis. The production of chemical change in an electrolyte resulting from the passage of electricity.

Electrolyte. A conducting medium or solution in which the electric current flows by virtue of chemical changes of decomposition and the consequent movement and discharge of ions in accordance with *Faraday's Law.*

Electrolytic Brightening. (See ANODIC TREATMENT.)

Electrolytic Cell. An electrically conducting medium in which two electrodes, the *anode* and *cathode,* are immersed for the purpose of producing an electrochemical action or enabling it to proceed.

Electrolytic Cleaning. The process of degreasing or descaling a metal by making it an electrode in a suitable bath. (E. 10.)

Electrolytic Corrosion. (See ELECTROCHEMICAL CORROSION.)

Electrolytic Cutting. A method of

cutting metals in which a rotating disc is pressed against the work and the electric current passes from the work through an electrolyte to the disc, rapidly removing the metal by electro-dynamic and electrochemical action. (S. 75.)

Electrolytic Deposition. The production of a metal from a solution of its salts by the passage of an electric current through the solution. (A. 27.)

Electrolytic Dissociation. The phenomenon occurring when an acid, base or salt is dissolved in water or any other electrolyte. A part or all of the molecules of the dissolved substance are broken up into parts called *ions* some of which are charged with positive electricity and are called *cations*, whilst an equivalent number, charged with negative electricity are known as *anions*.

Electrolytic Etching. (See ANODIC ETCHING.)

Electrolytic Grinding. (See ELECTRO-MACHINING.)

Electrolytic Oxalic Acid Etch. A test for the susceptibility of steel to *intercrystalline corrosion* in which a specimen is polished to a No. 000 emery paper finish and then given an anodic etch in 10% oxalic acid for 1½ minutes at 1 amp./sq. cm. Microscopic examination of the etched surface is carried out at a magnification of 250 to 500 diameters. The etching gives rise to three types of structure: (1) *Step structure*, in which the steps occur at the grain boundaries only; (2) *Dual structure*, in which there is some ditching at the grain boundaries but no grain is completely surrounded by ditches; (3) *Ditch structure*, in which one or more grains in the field are completely surrounded by ditches. According to the literature, step and dual structures indicate that the material would pass the *Huey test*, while a ditch structure would indicate failure in this test.

Electrolytic Oxidation. (See ANODIC COATING.)

Electrolytic Pickling. (*Cathodic Pickling.*) The descaling and cleaning of metals by electrolytic action in a conducting liquid in which the metal serves as some part of the electric circuit, e.g. the preliminary pickling of iron and steel may be carried out by cathodic action in a sulphuric acid bath of from 2% to 20% strength, the article being made the cathode and a current of 10 to 150 amperes per square foot of cathode surface used. The article is then subjected, with or without previous rinsing, to the electrolytic bright dip, in which it is made the anode in an electrolytic circuit having a sulphuric acid electrolyte of from 25% to 75% strength, the electric current being passed through the circuit at a density of from 80 to 250 amperes per square foot of anode surface and the temperature of the electrolyte being maintained below 40° C. In another method, which is particularly suitable for descaling alloys containing nickel or chromium or both, the metal or alloy is subjected to electrolytic action as anode in a bath comprising 30% or more concentrated sulphuric acid by volume with or without hydrofluoric acid, the sulphuric acid being in sufficient quantity to develop on the surface of the metal or alloy a partial passivity to prevent any substantial attack on the descaled metal or alloy by the acid bath and the current density being about 75 amperes and above per square foot of anode surface. (B. 63.)

Electrolytic Polishing. (*Jacquet Method.*) A method of treating metal surfaces in which the object to be polished is made to form the *anode* of an electrolytic cell, where it dissolves by electrolytic action and under certain conditions acquires a surface polish. The process is used, for example, in the preparation of micrographic specimens, reflecting surfaces and surfaces working under heavy loads. (M. 138.)

Electrolytic Protection. Protection from *electrochemical corrosion* by use of the protected material as *cathode* in the corrosion cell. (See CATHODIC PROTECTION.) (A. 27.)

Electrolytic Reduction. The removal of positive charges from, or the addition of electrons to, an atom or ion. It occurs only at the *cathode*.

Electrolytic Refining. (See ELECTRO-REFINING.)

Electrolytic Solution Tension Theory. (*Helmholtz Double Layer Theory.*) When a metal, or any other substance capable of existing in solution as ions, is placed in water or any other dissociating solvent, a part of the metal or other substances passes into solution in the form of ions, thus leaving the remainder of the metal or substances charged with an equivalent amount of electricity of opposite sign from that carried by the ions. This establishes a difference in potential between the metal and the solvent in which it is immersed.

Electrolytic Tinning. The electrodeposition of a protective layer of tin on metals. It can be carried out by two main methods, one acid and one alkali. In the acid method, the electrolyte is made up of a solution of stannous sulphate, cresol-sulphonic-acid, free sulphuric acid, gelatin and beta-naphthol.

In the alkali method, the electrolyte is a solution of sodium stannate containing small quantities of free caustic soda, sodium acetate and hydrogen peroxide. In both these methods, the amount of tin deposited is controlled by one or more of the following factors: the size of the tin anode; the ratio of the surface areas of cathode and anode; the distance between cathode and anode; the rate of travel of the strip; the density of the bath; and the electric current. (M. 128.)

Electrolytic Tool Sharpening. A process developed in the U.S.S.R. in which the tool to be ground and the grinding wheel are connected in a direct current circuit so that the tool forms the *anode* and the grinding wheel the *cathode*. By the action of the direct current in the *electrolyte* fed to the grinding point, metal is continuously removed from the surface of the anode. The inventor of this process claims that the removal of metal proceeds both by electrochemical and mechanical action on the anode. The passage of a direct current through the electrolyte causes the formation of a film of insoluble compounds on the anode, protecting it from further electrolytic action. This film is removed by the action of the grinding wheel forming the cathode, and a fresh surface of the metal is thus exposed to the action of the electrolyte, and thus assures the continuous removal of metal from the anode. This method was developed by *Gussev* and is sometimes known under that name. (N. 21.)

Electromachining. (*Electroerosion.*) The term covers a number of methods of disintegrating electrically conductive material by means of repetitive electrical discharges. (i) *Electroarcing*. This is performed by making the work the anode and maintaining an arc between the work and the cathode. Pulsating direct current of less than 25 volts potential is often applied through a moderately conducting electrolyte, such as a waterglass solution. The arrangement is particularly suited to rapid cut-offs of hard metals and carbides, and may be faster than a thin bort wheel. However, a purely electroarcing process results in somewhat rough surfaces. The electrical discharge is initiated by contacting the electrodes, and the current is carried by vaporized metal ions. The process commonly involves the deposition of some non-conducting film (such as silica) on the work; high local heating is evidenced by moderate consumption of the cathode. (ii) *Electrolytic Grinding*. A process which is usually done by revolving a metal disc cathode in close proximity to the workpiece, which is the anode, while an electrolyte flushes over the disc and workpiece in the same way that a coolant is applied to a grinding wheel. The system is adaptable to removing stock from electrically conductive bodies such as metals or metal carbides. Steady direct current, usually between 16 and 18 volts, and a highly conducting electrolyte are necessary; likewise, high current densities at the anode. A successful practical process hinges on discovery of a suitable electrolyte, and of effective control devices for spacing the cathode and anode, and for flowing the solution into the zone of electrolytic cutting. The action is characterized by low local heating and essentially no consumption of the cathode. (iii) *Electro-sparking Process*. Here, stock usually is removed by making the work one of the electrodes in a properly designed circuit. Rapidly pulsed current of the spark discharge type is passed between the work and the other electrode in a dielectric fluid. The method is especially suited to forming small diameter, deep holes of any shape and is characterized by relatively high electrode consumption. Voltage range is between 40 and 300. (See also SPARCATRON and METHOD X.) (iv) *Ultrasonic Process*. As differentiated from the electrochemical and electromechanical processes, the ultrasonic technique does not utilize current directly. Cutting or stock removal is accomplished by abrasive action at high frequency and low amplitude. Thus it is possible to process non-metals or non-conducting materials. The cutting or grinding tool usually is vibrated in the frequency range from 16,000 to 29,000 cycles per second through an amplitude of only a few thousandths of an inch. The abrasive, commonly 280-grit boron carbide, is carried in water to the tool and work. The tool itself also wears away during the operation. (See also CAVITRON PROCESS.) (v) Another process consists of a combination of the electrolytic method and diamond wheel grinding. A metal-bonded diamond wheel is used as the cathode, the diamond particles acting as insulating spacers, to separate the work from the wheel, and also as scrapers. (A. 22.)

Electromagnet. (See MAGNET.)

Electromagnetic Hardening. A method of controlling heat treatment which is based on the collapse of the magnetic properties of a steel at the *Curie Point*. Certain steels become decreasingly magnetic during the decalescence period and it is claimed that the correct quenching

temperature for many types of steel coincides with the point at which zero magnetism is attained.

Electromagnetic Hardness Analyser. A device for the detection of variations in the hardness of a steel surface. The specimen is demagnetized and then rotated and strongly magnetized whilst its magnetic field is explored by means of a special magnetic pick up in which weak currents are induced by any fluctuations in the magnetic field caused by variations in the hardness of the surface.

Electromagnetic Separation. A method of separating magnetic ores, e.g. haematite from the gangue in which the crushed material is carried on an endless belt over powerful electro-magnets whereby the magnetic mineral is retained and the gangue discarded.

Electromechanical Machining. (See ELECTROMACHINING.)

Electromechanical Method X. (See METHOD X.)

Electrometallization. The electro-deposition of a metal on a non-conducting base for decorative or other purposes.

Electrometallurgy. The application of electrochemistry or electrothermics to metallurgical process. (B. 103.)

Electromotive Force. (*e.m.f.*) Force developed in a cell, accumulator or generator which causes an electric current to flow. The unit of electromotive force is the *volt*.

Electromotive Series. (See ELECTROCHEMICAL SERIES.)

Electron. Sub-atomic particle having a mass 1/1840 that of a hydrogen *atom*, and bearing a negative electric charge.

Electron Bombardment Furnace. In this furnace, a filament placed near a crucible of conducting material is electrically heated and the unit is in a chamber in which a high degree of vacuum is maintained by a high-speed oil diffusion pump. Electrons from the filament bombard the crucible shells, liberating their energy mainly in the form of heat. Temperatures up to 2850° C. have been obtained, and in one instance a tantalum shell was melted using only 700 watts. This furnace is used for preparing specimens of alloys containing such metals as titanium, vanadium, zirconium, columbium, and platinum, in order to study equilibrium diagrams. (H. 81.)

Electron Bonding. A term in nuclear physics designating those cohering forces which act between the electrons of neighbouring metal atoms to create an aggregate metal or alloy.

Electron Compound. An intermediate phase in an alloy system of which the crystal structure and composition are both controlled mainly by the establishment of a certain electron/atom ratio. (H. 82.)

Electron Defectoscope. An instrument for detecting faults in rails, at speeds of 10 to 25 km. per hour. The essential part of the instrument is a thermionic valve in which the top of the glass bulb is flattened. The semi-cylindrically shaped *anode* has its concave surface turned towards the flat top of the glass bulb, the heated *cathode* wire filament being placed at the axis of the semi-cylindrical anode and as near as possible to the flat surface of the bulb without overheating the glass. The valve is used upside-down with the flattened top of the bulb near the surface of the part being examined. When moved along the surface of the part magnetized by means of any suitable direct current magnetizing system, the uniform magnetic field produces a constant effect on the electron stream from the cathode to the anode and consequently on the anode current of the search valve, while local variations in the magnetic field produce sudden changes in the anode current. The output of the search valve is amplified by applying it to the grid of an ordinary amplifying valve, the output of the latter being used to work an indicating device such as a milliammeter, a sensitive relay or an oscillograph. By adjusting the grid bias of the amplifying valve, the effect of a steady magnetic field on the output of the search valve is neutralized and the indicating device made to work only when a flaw causes a sudden change in output. (G. 35.)

Electron Microscope. An instrument analogous to the *optical microscope*, whose tremendous resolving power is rendered possible by the fact that *electrons*, when accelerated by a pressure of the order of 50,000 volts, have many of the properties of light waves and can be focused by electrical and magnetic fields in the same way that light can be focused by a lens. As the effective wave-length of the electron waves is 1000 times less than that of light, a corresponding increase in resolving power would appear possible. In practice this is not realized completely, but magnifications as high as 100,000 have been used and detail smaller than 10^{-6} cm. resolved and observed. The use of the usual electron microscope cannot be quite the same as in the case of the metallurgical microscope in which the specimen is observed by light reflected from the surface of the specimen.

Scattered electrons from the specimen surface can be collected from the surface of a metal, and this is done in the *scanning electron microscope*; but in the more usual instrument the electrons pass through a thin sample and are collected by a lens. Differences in transparency in different parts of the object are recorded on the photographic plate, but since electrons are readily absorbed, only very thin objects can be viewed. In practice, it is not possible to prepare specimens of metal from normal metallurgical samples of sufficient thinness and the difficulty is met by the preparation of a replica of the surface in a suitable material. (S. 160.)

Electron Theory. An explanation for *passivity* based on the supposition that a subtle sharing of electrons occurs between the iron and chromium atoms in stainless steels greatly reducing the subsequent chemical tendency of the steel to react with corrosive environments.

Electronegative. Radicals which behave as negative ions, radicals taking up electrons thus acquiring a negative charge, when united with other radicals by electrovalent bonds. The halogens, oxygen, sulphur and other non-metals, are generally electronegative.

Electronegative Potential. A potential corresponding in sign to those of the active or anodic members of the *e.m.f.* series. (See ELECTROCHEMICAL SERIES.) (E. 10.)

Electronic Fatigue Machine. A fatigue testing machine designed to vibrate a rectangular-section specimen at much higher frequencies than are attained with more conventional equipment. The drive is obtained from a moving-coil unit fed from an oscillator which is synchronized by feed-back from a photoelectric cell illuminated by a light beam crossing the specimen. (G. 52.)

Electronic Heat Control. A device for adjusting the heating value (rms value) of the current in making a resistance weld by controlling the ignition or firing of the tubes in an electronic contactor. The flow of current is initiated each half-cycle at an adjustable time, with respect to the zero point on the voltage wave. (A. 37.)

Electronic Instagraph. An optical instrument for measuring and automatically recording the temperature of a moving body passing across the field of the sighting tube. (S. 111.)

Electronic Thickness Gauge. (See MEASURAY.)

Electronic Torch. A term applied to a method developed to attain temperatures up to 3370° C. and over. Radio waves of very high frequency, generated by a magnetron, are used to form an arc between the ends of two concentric cylinders. If certain gases (e.g. carbon dioxide, or nitrogen) are blown through the arc, high temperatures are produced on any surface placed in the jet. Monatomic gases (e.g. argon, or helium) do not give this effect, which is presumably due to recombination of gas atoms on the surface. The temperature developed will melt tungsten. (G. 8.)

Electronic Tornado Process. A method of automatic carbon arc welding used for the production of thin (·010 in.) composite sheet. (S. 48a.)

Electronicast Process. An *investment casting* process. Some wax patterns are used, but in general, a polystyrene plastic is employed. The patterns are dipped first in a silica slurry and when this is dry, a box is placed over the coated pattern and filled with the secondary investment. The moulds are then dried in an electric oven and "burned out" in a gas-fired oven. Moulds are filled with metal, melted by induction heating, either by centrifugal methods or by a process in which the metal is drawn in by vacuum. (R. 42.)

Electronics. The branch of science relating to the conduction of electricity through gases or a vacuum.

Electronik Continuous-Balance Potentiometer. An instrument in which the potential produced by the thermocouple is not applied to a galvanometer but is converted to alternating current, amplified by electronic means, and applied directly to actuate the balancing motor which moves the slide-wire contact and the pointer or pen. Temperature changes as small as 0·06° F. in a range of 100° F. can be continuously recorded with a simple mechanism. (S. 133.)

Electroosmosis. The phenomenon occurring when two electrodes are inserted into water and an electric current made to pass between them, the water migrating from the positive to the negative pole.

Electropainting. A method of painting based on the fact that if an electrostatic field is set up between a high voltage electrode and a conductor at earth potential, and a spray of paint directed at the conductor in such a way that it passes through the electrostatic field, then the individual particles of paint are ionized, and attracted to the surface of the conductor. (W. 11.)

Electrophat Process. A Hungarian process for the coating of steel and aluminium. Phosphoric acid solution containing zinc phosphate is used as the

electrolyte and the metal is first subjected to electrolysis, keeping it as the anode. A current density of 3 amp./dm^2 is used for 3 to 5 minutes and the polarity then reversed so that the metal, now acting as a cathode, receives a velvety grey deposit of zinc which can be highly polished; it also acts as a good primer surface on which highly adhesive coatings of nickel, chromium or copper may be deposited.

Electrophoretic Finishing. A method of depositing rubber. The latex mix used, which may contain 35% by weight of rubber also contains accelerators, sulphur, zinc oxide and other materials, all of which migrate to the anode, are homogeneously incorporated in the deposit and serve their usual functions. The anode compartment contains the ammonia-latex mix and the article to be coated and is separated from the cathode compartment by porous diaphragms. The catholyte is slightly alkaline water. The pH must be correct. If it is too low, the deposits are soft and may crack on drying. If too high, they have too high an electrical resistance and may overheat. Zinc is preferred as the anode material but other materials can be used. When an e.m.f. is applied, zinc ions pass into solution and neutralize the rubber particles, which precipitate on the anode. (R. 36.)

Electroplating. The production of a thin firmly adherent coating of one metal on another by *electrodeposition*. (Cf ELECTROTYPING.)

Electropolishing. An abbreviation for *electrolytic polishing*.

Electropositive Potential. A potential corresponding in sign to potentials of the noble or cathodic members of the *e.m.f.* series. (See ELECTROCHEMICAL SERIES.)

Electrorefining. (*Electrolytic Refining.*) The operation of purifying a metal by electrolytic solution and redeposition.

Electroscope. A device for the detection of small electrical charges.

Electrosonometer. A device for measuring the torsional and flexural characteristics of most solid materials. Its use can be extended to the field of concrete, wood, metals, plastics, etc. It is claimed that measurements are easily made with the instrument. The driver is placed at one end of the sample under test in such a position as to drive the sample in flexure or torsion. Sufficient power is fed into the driver to cause the sample under test to vibrate. By tuning the oscillator through its frequency range, the modes of vibration and resonant frequencies can be determined through the use of the portable pick-up, resonance indicator and cathode ray oscillograph. Phase relationship between the driver voltage and the pick-up voltage can be shown with the aid of the oscillograph.

Electrostatic Method for the Determination of Young's Modulus. In this method a variable frequency precision oscillator is used to vibrate the sample through an electrostatic drive. The condition of resonance is ascertained by an electrostatic pick-up, feeding into the high impedance first stage of a 100-decibel amplifier. Using a steel cylinder (¼ in. diam., 4 in. long) Young's modulus can be measured in the range 85° to 373° abs.; the accuracy is of the order of one part in ten thousand. (J. 3.)

Electrothermic Process. (*Tanna Process.*) A steel-making process in which iron ore is reduced by the carbon and other elements contained in a bath of pig iron heated by induction. The method is offered as a partial solution to the scarcity of metallurgical coke in Argentina. One or more induction furnaces and a cupola are used. Pig iron is melted in the cupola and transferred to the induction furnaces. Ore is added. Alternatively, cold pig iron may be melted in the induction furnaces and 60% to 70% of steel scrap added. Additional refining is effected by oxides such as ore, pyrites, ash, ferruginous sands, mill scale, etc. (T. 3.)

Electrothermics. The application of electrical energy to the production of heat in chemical or metallurgical processes.

Electrotype Metal. A lead base alloy containing about 3% tin and 4% antimony.

Electrotyping. The reproduction, usually in copper, either in relief or intaglio. A cast of the article is formed and this is rendered conducting by coating with graphite. The cast is then made the cathode in an electrolyte consisting of a solution of copper sulphate, whilst the anode is of copper. In electrotyping the coating thus deposited is not adherent as in *electroplating*, but is intended to be removed from its base, i.e. the cast of the object being copied.

Electrowinning. (See ELECTROEXTRACTION.)

Element. (*a*) A substance consisting entirely of atoms of the same atomic number. (*b*) A term often used to denote the resistance wire and former of a resistance type of electric heater. Also used to denote one of the electrodes of a primary or secondary cell. (*c*) Of an accumulator, an assemblage

of two groups of opposite polarity with or without separators or diaphragms.

Element Line. (See ANALYSIS LINE.)

Elephant. A term used in the paper trade for large sheets of paper, the size varying according to the type of paper concerned. Brown paper 34 × 24 in.; drawing paper 28 × 23 in.; printing paper 23 × 30 in.

Elhuyar, Fausto de. (1755–1832.) A Spanish chemist, who first prepared metallic tungsten in 1792.

Elin-Hafergut Verfahren. (*E.H.V.*) (See FIRECRACKER WELDING.)

Elkem Furnace. A rotary hearth type of electric furnace developed for the production of ferro-alloys and calcium carbide. (E. 13.)

Elliott Optical Pyrometer. In this instrument temperature readings are obtained by matching the variable light emitted from a standard lamp filament, incorporated in the instrument, to the brightness of the heated object. It is claimed that this pyrometer is a reliable and convenient means of determining very high temperatures, e.g. in electric arc and metallurgical hardening and annealing furnaces.

Ellipsoid Furnace. The furnace consists of two cylinders bolted together and mounted at one end on a universal joint, whilst centrally it rests on two roller bearings so that the furnace is tilted. The upper end of the furnace is closed by a circular door which carries an oil burner mounted on a pedestal. The pedestal is hollow and carries the air supply to the burner. The furnace is controlled by a switch gear mounted on a column carrying the canopy, superimposed above the furnace, and it can be rotated in either direction. When working on cast iron the time taken for melting a 10 cwt. charge was 1 hour 40 minutes. (F. 29.)

Ellira Welding Process. (See UNION MELT WELDING.)

Elongation. (*a*) The total extension produced in a *tensile test* and determined after fracture by holding the pieces of a fractured tensile test piece together and measuring between *pop marks* applied before starting the test. It is expressed as a percentage of the original *gauge length*, which should also be given, and 2 in. is a common standard in this country. It is a measure of the *ductility* of the steel. (*b*) In rolling, the ratio of the length of the piece after it has passed through the mill, to its original length.

Eloxal. A generic term used in Germany, for *anodic oxidation*.

Elutriation. A method of separation of grain sizes according to the final sinking velocities of the grains in a liquid medium.

Embossing. (See COINING.)

Embrittlement. Structural instability (brittleness) produced for example: (i) by caustic embrittlement where under steady high stresses and in the presence of a strong alkali solution, *intercrystalline* cracks appear; (ii) by *hydrogen embrittlement* which appears to be due to the inter-molecular penetration of the steel by nascent hydrogen. This type of embrittlement which occurs after *pickling*, is not permanent and may be eliminated by *ageing*, or by soaking the steel in boiling water before *cold working*. (See also TEMPER BRITTLENESS.)

Emco Tester. A portable hardness tester, which although designed on the Rockwell principle, can be used for Brinell, Vickers or similar tests if a microscope is available. The testing head, which can be used in a stand, a portable C-clamp, or other special fitting, contains a pair of concentric springs for applying minor and major loads (e.g. 10 kg. and 150 kg. for the Rockwell C test), and a dial gauge for measuring depth of impression. The indenting tools and sealed boxes containing the springs are interchangeable so that the type of test can be changed readily. The minor load is applied by bringing the indenting tool into contact with the material and the major load by movement of a hand lever. (T. 48.)

Emery. An abrasive consisting of a mixture of alumina and iron oxide. It is an impure form of *corundum*.

e.m.f. *Electromotive Force*.

Emissive Power. (See EMISSIVITY.)

Emissivity. (*Emissive Power.*) The ratio of the rate of loss of heat per unit area of a surface at a given temperature to the rate of loss of heat per unit area of a *black body* at the same temperature and with the same surroundings.

Emmel Process. A process used for making high-duty cast iron, which consists in using a high percentage of steel scrap in the cupola charges along with high-silicon pig iron and common ferro-manganese or spiegel additions. The process has now been superseded. (W. 52.)

E.M.T. Abbreviation for *Electric Metallic Tubing*.

Empty Sinking. A term employed in the manufacture of tubes for the operation of drawing without a restrictive mandrel. (S. 158.)

Emulphor STH. A wetting agent and pickling inhibitor, which is claimed to give excellent metal-surface protection

against sulphuric acid attack without altering the rate of acid attack against the oxide appreciably. It shows excellent adhesion to the metal surface so that after-treatment may be delayed several days without rerusting of the metal. (H. 4.)

En Specifications. A series of specifications relating to wrought steels for automobile and general engineering purposes scheduled in British Standard 970.

End Centred. The term, used in connection with an orthorhombic space lattice, denotes that it has equivalent points at the corners of the unit cell and at centres of the pair of opposite faces perpendicular to the central axis. It is the same as *side centred*, with a different choice of axes. (A. 27.)

End Effect. The thickening of the walls at both ends of a butt welded pipe where tension cannot be applied.

End Hardening. A method of increasing the wear resistance of rails in which the temperature of the surface of the rail head is raised by gas flame or induction heating and the part is then subjected to rapid cooling by means of compressed air.

End Measurement. A measurement made by contacting the ends of the object by means of a *micrometer*, *vernier gauge*, etc.

End Quenched Bar Test. (See DE VRIES.)

End Quench Test. A standard *hardenability* test in which the test piece is quenched at one end and the hardness is measured at predetermined intervals along the length of the test piece from the quenched end. (See JOMINY TEST.)

Endlichite. $(PbCl)\ Pb_4(V,AsO_4)_3$. A vanadium ore.

Endogas. A mixture of carbon monoxide, hydrogen, nitrogen and a little methane, formed by the *endothermic reaction* of a hydrocarbon fuel and air. The gas is used to form protective atmospheres in heat treatment furnaces. (G. 15.)

Endosmometer. An instrument to measure the rapidity of the passage of a less dense fluid through a membrane which separates it from a denser fluid.

Endothermic Atmosphere. An atmosphere consisting of *Endogas*.

Endothermic Reaction. A chemical reaction in which heat is absorbed.

Entrance. (See DIE ENTRANCE.)

Endurance Curve. (See S/N DIAGRAM.)

Endurance Limit. In fatigue testing, the value of the applied alternating stress which will produce fracture after a given number of reversals. (Cf. FATIGUE LIMIT.)

Endurance Ratio. The ratio of the endurance limit for cycles of reversed flexural stress to the *tensile strength*.

Energizer. A substance added to carburizing mixtures to accelerate the *case-hardening* process. The energizers most generally used are barium or sodium carbonates whose action is similar to a catalyst. It is believed that the energizer provides carbon dioxide, which in turn reacts with incandescent carbon to form an additional supply of carbon monoxide. (F. 48.)

Energy Product Curve. (See MAGNETIC ENERGY PRODUCT CURVE.)

Engineers' Appointments Bureau. (See PROFESSIONAL ENGINEERS' APPOINTMENTS BUREAU.)

Enlund Test. A rapid test for the determination of the carbon and alloy content of steel by the measuring of its electrical resistance.

Enthalpy. The heat content per unit mass expressed in B.Th.U. per pound. When a change occurs at constant pressure, as when water is boiled, the change in enthalpy is equal to the heat added, i.e. *latent heat*.

Entrainment. The carrying over of liquid or solid particles by the velocity of a vapour.

Entry Guide. (See GUIDES.)

Epidiascope. An apparatus for throwing upon a screen an enlarged image of an opaque object, e.g. a photographic print, letterpress, etc.

Epitaxis. The mechanism by which a continuous crystalline structure, on an atomic scale, is formed, joining the base metal and a surface deposit, which may be another metal or an oxide or corrosion product. (C. 10.)

Epstein Hysteresis Tester. (*Epstein Square.*) An apparatus for determining the hysteresis and eddy current loss of a sample of electrical iron sheet at a specified frequency and flux density and given wave form. Samples cut from the sheet are assembled in a rectangular magnetic circuit, upon which windings are placed, and the power taken to magnetize the iron is measured by means of a *wattmeter*.

Epstein Square. (See EPSTEIN HYSTERESIS TESTER.)

Equalizing. Maintaining a forging at a constant temperature for a sufficient time to obtain a uniform temperature throughout the mass.

Equiangular Rosette. (See STRAIN ROSETTE ANALYSIS.)

Equiaxed Crystals. (*Free Crystals.*) Crystals which have been allowed to form freely from solution with the result that their axes are approximately equal in length.

Equilibrium. (*a*) The condition attained in a reversible chemical reaction when the reaction velocities in opposing directions are equal. It may be considered that a state of equilibrium exists in an alloy at any given temperature when a further period at that temperature does not produce any change in constitution, provided that the temperature in question is high enough to allow the constitutional changes to proceed to completion. (*b*) The balancing of two or more forces in such a way that their combined effect is the same as if there were no forces acting and the body on which they act, if at rest, remains at rest.

Equilibrium Diagram. (See PHASE DIAGRAM.)

Equitron. A device for supporting the test bar in the *Jominy test.*

Equivalent Section. (See RULING SECTION.)

Equivalent Weight. The mass of a substance which, in a specified chemical reaction, combines with or replaces 8 gm. of oxygen. (B. 103.)

Er. Chemical symbol for *erbium.*

E.R.A. Electrical and Allied Industries Research Association.

Erbium. (*Er.*) *Atomic weight* 167·2. *Specific gravity* 9·16. A rare earth metal, one of the rare earth group. It is trivalent forming the oxide Er_2O_3 but owing to its rarity few data are available regarding its physical constants. For the same reason it has as yet no commercial uses.

Erg. The unit of work or energy in the c.g.s. system of units; equal in magnitude to the work done when the point of operation of a force of one dyne is allowed to move one centimetre in the direction of the force.

Erical Mould. An ingot mould whose walls can be pressed inwardly (e.g. by external pressure, or by tension derived from prior distortion) during the solidification of the steel or other metals. The object of the invention is to eliminate pipe and it is claimed that the effect of this pressure and subsequent movement on the crystals in the half solidified condition is similar to that of rolling, or pressing as fissures are eliminated, and the finished ingot has remarkably fine crystals. (E. 79.)

Erichsen Test. A cupping test, using a tool with a spherical end of 20 mm. diam, to deform the test piece, which is held between annular jaws of 27 mm. internal diam. The test sheet, which is 3½ in. square, is first clamped between the jaws to measure the thickness; the jaws are then moved apart by 0·05 mm. and clamped in that position, to allow the metal to be drawn into the cup as the test progresses. The tool is pressed into the metal until a crack appears in the cup, and the depth of cup at this instant is taken as a measure of the *ductility* of the metal. (G. 37.)

Ernst Hardness Tester. (*Mandurometer.*) A Swiss hand-operated portable hardness tester. It has a range of 100 to 400 Brinell. The movement of the indenter is transmitted to a diaphragm above which is a vacuum filled liquid chamber in direct communication with a small opening in a transparent capillary tube. The zero mark on the scale is set before testing to coincide with the end of the coloured liquid in this tube, and in the test the hardness is indicated by the movement of the liquid.

Erosion. The abrasion of metal or other material by liquid or gas, usually accelerated by pressure of solid particles of matter in suspension, and sometimes by *corrosion.* (A. 27.)

Erosion Boring. Drilling holes in steel by means of an underwater arc between an electrode and the steel.

Erosion-Corrosion. The combined effect of *erosion* and *corrosion*, in which the surface film., e.g. the oxide, sulphate or gas film, on which most metals and alloys depend for their corrosion-resisting qualities is continuously removed by mechanical means, e.g. erosion, and the fresh unprotected metal is thus exposed to corrosive action with resulting progressive deterioration. (L. 53.)

Erosion Scab. A casting defect occurring where the metal has been agitated, or boiled, or has partially eroded away the sand, leaving a solid mass of sand and metal at that particular spot. (A. 26.)

E.R.W. (Electric Resistance Welding) Process. A method of producing welded steel boiler tubes in which the tubing is manufactured continuously, the welding contact being made through rolling electrodes. Alternating current is used, but the frequency is increased from the 50 cycles per second of the mains to 200 to 350 cycles per second, according to the size of the tube, to give the most efficient welding conditions. (S. 60.)

E.S.S. Welding Process. A semi-automatic process which is a combination of the *Elin-Hafergut* and the *Unionmelt Processes.* A bare wire electrode is laid horizontally in the welding groove which has previously been filled with flux powder of the type used in Unionmelt welding. The object of this bed of flux is two-fold. First, to insulate the bare wire from the workpiece and

secondly, to control the arc length. The end of the electrode rests on a piece of steel wool or piece of carbon which ignites the arc when the welding current is switched on. Before this is done, the electrode is completely covered over its entire length with flux powder, the depth of the layer depending on the size of the rod. The arc burns underneath the protecting layer of flux which prevents oxygen and nitrogen from penetrating into the weld; the process is, therefore, a *submerged arc process*. The electrode is connected to the positive pole of the D.C. welding set, the workpiece to the negative pole. A.C. welding has also been tried successfully. The powder on top of the electrode is melted during the welding and forms a layer of slag which protects the weld against the harmful effect of too rapid cooling. (W. 57.)

Etch Figures. Markings caused by an etchant on a crystal surface and usually related geometrically to the *crystal structure*. When the alloy consists of only one phase the various grains, after etching, usually appear to be of different degrees of brightness. This phenomenon is dependent upon the direction of the incident light.

Etch Test. A test used in standard manufacturing and fabricating processes to determine the soundness of internal structures. A test piece is cut from the desired location in a bar and from this a specimen of the size required for etching is removed. The surface to be examined is polished and then dipped in a solution of hydrochloric, sulphuric, nitric or picric acid. For some products, solutions of iodine, copper ammonium sulphate, ferric chloride, cupric chloride or cupric sulphate are used. By this means the presence of any slag streaks or porosity is detected and the direction of the flow lines is revealed.

Etchant. (See ETCHING REAGENT.)

Etchant to Reveal Temper Brittleness. (See ZEPHIRAN CHLORIDE.)

Etchell's Furnace. (See GREAVES-ETCHELL'S FURNACE.)

Etching. A process of revealing the structure of metal by removal of the cold worked metal produced on the surface during the polishing operation, followed by selective chemical attack of the structure. This is rendered possible by the fact that the differently orientated crystals have different rates of solution in the *etching reagents*. For example, in *pearlite*, the *ferrite* lamellae are electro-positive to the *cementite*. (See also ANODIC- and DEEP-ETCHING.)

Etching Pits. Small cavities formed on the surface of metals during *etching*.

Etching Reagent. A means of revealing the structure of a metal or alloy by differential corrosion effects, thus the different constituent parts of the various grains can be distinguished. This substance is usually a solution of the reagent in water, acid or alkali, but etching may in some cases be brought out by a differential oxidation produced by *heat tinting*.

Etolizing. A proprietary method of electroplating porous metal powder parts. The process eliminates the spotting-out condition, and the method is based on the principle that the residual plating salts are volatilized out of the pores by heat treatment, in contrast to the usual method of washing out such salts by solution in hot water or some other solvent. The process has been successfully applied to coat porous iron, brass and bronze parts. Coating metals have included copper, nickel, silver, copper-nickel, and copper-tin. Chromium is satisfactory provided a very dry atmosphere is used during heat treatment. (K. 56.)

E.T.S. Electrodepositor's Technical Society.

Ettinghausen Effect. The temperature difference produced in the two edges of elongated iron plate through which an electric current is flowing when a magnetic field is applied at right angles to it.

E.T.U. Electrical Trades Union.

Eu. Chemical symbol for *europium*.

Eudiometer. A long graduated glass tube used in gas analysis.

Eugene Hardness Tester. A machine for measuring the hardness of either thick or very thin objects or of deposits in very thin layers. A diamond indenter is used, and the load is applied by means of a balanced steelyard carrying weights at the end and also a jockey weight. The indentation is measured by an arrangement on the principle of the optical lever which indicates the extent of movement of the part carrying the indenter. The indentations may be as small as 0.1 mm. (E. 82.)

Europium. (*Eu.*) *Atomic weight* 152. *Melting point* about 1100° C. *Specific gravity* 5·24. A rare metallic element, a member of the rare earth group. It is trivalent forming the oxide Eu_2O_3. Owing to its rarity few data are available concerning its physical constants, and for the same reason it has as yet, found no commercial use. It is found in very small quantities in *monazite*.

Euscope. A grain size comparator. (A. 28a).

Eutectic. A mixture of definite composition, consisting of two or more con-

stituents, which solidifies out of the liquid at a minimum freezing point. This point occurs at the intersection of two descending *liquidus curves* in a *binary* system or three descending liquidus curves in a *ternary* system.

Eutectic Alloy. In an alloy system, the composition at which two descending liquidus curves in a binary system or three descending liquidus curves in a ternary system meet at a point. Thus, such an alloy has a lower melting point than neighbouring compositions. More than one eutectic composition may occur in a given alloy system. (A. 27.)

Eutectic Carbide. Carbide which forms during freezing as one of the mutually insoluble phases participating in the eutectic reaction of ferrous alloys. The so-called permanent carbides are largely eutectic carbides forming during original solidification of the ingot. (Z. 4.)

Eutectic Change. The transformation from the liquid to the solid state in a *eutectic alloy*. It involves the simultaneous crystallization of two constituents in a binary system and of three in a ternary system.

Eutectic Melting. Melting of local micro areas that are the same as the *eutectic* in average composition. On cooling rapidly, these areas solidify into a typical eutectic structure. (A. 27.)

Eutectic Reaction. A reaction in which a liquid solution solidifies or transforms at constant temperature to form a solid mass made up of two kinds of crystals. The reaction occurs at a point which is a minimum on the liquidus line of the phase diagram. During the reaction the compositions of the liquid phase and the solid phases remain unchanged. The reaction is reversible.

Eutectic Solder. An alloy which contains 62% tin and 38% lead, and melts at 183° C.

Eutectic Structure. The characteristic arrangement of the constituents in a *eutectic* resulting from their simultaneous crystallization from the melt.

Eutectic System. An alloy system in which one alloy crystallizes out at a lower temperature than that of the other constituents of the system.

Eutectoid. A mixture of two or more constituents which forms on cooling from a *solid solution* and transforms again on heating, e.g. *pearlite*. The essential difference between a *eutectic* and a eutectoid is that the eutectic is formed from the melt whereas the eutectoid is formed from a solid. (See Plates VII (c) and IX (a) and (b).)

Eutectoid Point. The point on the *equilibrium diagram* which indicates the composition of the *eutectoid* and the temperature at which it is formed.

Eutectoid Steel. A plain carbon steel containing about 0.83% carbon, which, with suitable conditions of cooling, consists entirely of the *eutectoid* constituent, *pearlite*.

Eutectrol Process. A process for *continuous gas carburizing*. The gaseous mixture used consists of a hydrocarbon gas containing from 8% to 10% of carbon dioxide mixed with the products of combustion of the furnace. The furnace consists of a muffle chamber, with a purging chamber at the charging end and a cooling chamber at the discharging end. Both of these chambers are separated from the muffle by gas valves. The furnace is heated by gas burners firing above and below the muffle. The carburizing gas and the work travel through the muffle in the same direction. A case depth of 0·045 in. can be obtained in three hours. (H. 53.)

Euxenite. A mineral consisting essentially of a niobate and titanate of *yttrium*, *erbium*, *cerium* and *uranium*. It contains very small amounts of *germanium*. (D. 4.)

Evacuated Die Casting Process. A process for the production of finned cylinder-heads. The die is built up, where the fins occur, from banks of blades. These blades are in contact at the fin tips, and air is drawn from between the blades. The process is not analogous to pressure casting in reverse, since the metal is not drawn into the die by the vacuum but flows normally under the influence of gravity. As the level of the metal rises in the die, pairs of blades are shut off from the atmosphere and the air between them is withdrawn, helping the metal to run to the extremity of the fin without the tendency to misrun (due to an air cushion) or to entrap air bubbles in the fin. (M. 81.)

Evans Cell. A nitrogen-oxygen cell with iron electrodes and sodium chloride electrolyte.

Evans' Effect. A term used for the effect produced when two like electrodes are immersed in identical solutions, where if one electrode is aerated, the other not, a potential is set up. (R. 10.)

Evans Mill. A mill in which a series of small-diameter migratory rolls travel through the gap between a large-diameter roll and a fixed semi-cylindrical cross-member or anvil which backs up the small rolls. The strip passes round the single large roll through which the torque for rolling is transmitted and is rolled between it

and the small migratory rolls. The reduction is effected by the contour of the inner surface of the cross-member, which is such that the gap between it and the large roll is narrower at the exit than at the entry end. (K. 12.)

Evaporation. Conversion of a liquid into vapour, without necessarily reaching the boiling point.

Evaporation Coating. (See VACUUM METALLING.)

Evaporative Power. The heating power of a fuel expressed as the number of pounds of water at 212° F. changed into steam at the same temperature by 1 lb. of the fuel.

Ewing Extensometer. An instrument used to measure the *elongation* of a test piece under tensile stress. The elongation after being magnified mechanically is determined by means of a measuring microscope.

Excite. In X-rays, to cause to be emitted. (A. 27.)

Exciting Current. (See CURRENT, EXCITING.)

Exfoliation. A type of corrosion that progresses parallel to the outer surface of the metal, causing layers of the metal to be elevated by the formation of corrosion products. (See also SPALLING.) (A. 27.)

Exhaust Gases. The gaseous products of combustion of an internal combustion engine or gas turbine after they have done mechanical work.

Exothermic Reaction. A chemical reaction in which heat is given out.

Expanded Metal. Sheet metal which has been cut in such a manner that on stretching a metal network is formed. It is used as a reinforcing medium, e.g. in concrete and plaster work. (Cf. EXPANDING METAL.)

Expanding. (See BULGING.)

Expanding Mandrel. (See MANDREL.)

Expanding Metal. An alloy of bismuth, which expands on cooling and solidifying, e.g. 2 parts antimony to 1 part bismuth. (See also TYPE METAL.)

Expanding Test. (*a*) (*Flaring Test.*) A test for steel tubes in which the end of the tube is expanded by a predetermined amount. (*b*) A test for wrought iron wheel centres in which a succession of tapered mandrels are driven into the bored out boss until the boss bursts or is expanded sufficiently to prove the quality of the iron and workmanship.

Expansion Scabs. Rough thin layers of metal partially separated from the body of the casting by a thin layer of sand, and held in place by a thin vein of metal. (A. 26.)

Expansivity. (See THERMAL EXPANSION.)

Expendable Material. Material which can be removed, e.g. the material of a pattern in the *Lost Wax Process* in which the pattern is expelled from the mould by melting and burning.

Explosion Bulge Test. A method for semi-work-scale testing of full welds in heavy plate under combined stress conditions such as prevail in structures. The test consists of bulging welded plate in diaphragm fashion. Uniform loading of the test plate is accomplished by means of an air blast set up by the detonation of an explosive. By modification of bulge geometry it is possible to obtain a wide range of stress fields. (H. 23.)

Explosive Grain Growth. The abnormal propensity to grain growth of certain materials when heated to high temperatures. Owing to the rapidity with which the phenomenon occurs it is sometimes aptly termed explosive. (K. 26.)

Explosive Rivet. A type of blind fastener in which a hollow shank rivet is used, containing an explosive charge. The rivet shank is expanded by exploding the charge after the rivet has been inserted. (A. 27.)

Extension. (See ELONGATION.)

Extensometer. An instrument for measuring minute extensions of the test piece during a *tensile test.*

Extraction. (*a*) The science and technique of obtaining metals from their ores. (*b*) A metallic content obtained from the ore.

Extra Lattens. Hot rolled sheets having a thickness of less than 0·0174 in.

Extrapolation. A method of assigning values by extending a plotted curve for a certain distance beyond those which have been actually determined, on the assumption that there will be no sudden change in the nature or form of the curve and the corresponding values.

Extra Spheroidization. The additional spheroidization produced by any inequality in the heat treatment, such as slower heating up, slight difference in soaking temperature, slow cooling, or retempering. (D. 22.)

Extruding. (See EXTRUSION.)

Extrusion. The term, as applied to metals and alloys, comprises essentially the application to a relatively massive billet or blank, of sufficient pressure to cause the metal to flow through a restricted orifice, thereby forming a greatly elongated section, of uniform but less massive volume. In ***hot extrusion,*** the metal is above its ***recrystallization temperature,*** and thus continuously recrystallizes and is not ***work hardened*** during the process. In ***cold extrusion,***

the metal does not reach the temperature of incipient *recrystallization* and may, therefore, be considerably work hardened by the process. In the production of seamless tubes from a hot billet, the latter is forced to flow through a *die* over a mandrel positioned centrally in the die. (C. 56.)

Extrusion Billet. A short length of round billet or hot rolled bar, either solid or drilled with a central hole, depending on the size and the material.

Extrusion Discard. (*a*) In the production of seamless tubes, a small portion of billet left in the container at the end of the stroke of the extruding ram. (*b*) A short length cut from the front end of an extruded tube.

Extrusion Finish. Smooth-coated wire suitable for the production of bolts by *cold-heading* and *extrusion*.

Eye. A loop formed at the end of a bolt, steel wire, spring plate or the like.

Eye Bolt. A bolt with a ring welded on to the end.

Eyepiece. The lens or system of lenses in an optical instrument, to which the observer applies his eye, when using the instrument.

F

f. (See FINISH MARK.)

F. (*a*) Chemical symbol for *fluorine*. (*b*) A French symbol for a smooth, glittering and oblique fracture. (*c*) Abbreviation for flat welding position.

°F. (See FAHRENHEIT.)

Face. (*a*) In a twist drill, that portion of the flute surface adjacent to the lip on which the chip impinges as it is cut from the work. (*b*) In crystallography, a natural surface, or a cut surface parallel to a possible natural surface.

Face Centred Cubic Iron. A term for *gamma iron* or *austenite* referring to its characteristic *face centred lattice*.

Face Centred Cubic Lattice. An arrangement of *atoms* in crystals in which the atomic centres are disposed in space in such a way that they may be supposed to be situated at the corners and the middle of the faces of a set of cubic cells, i.e. that lattice possesses half an atom in the middle of each face of the cubic lattice, the corners each sharing one atom with seven other cubes. The facial atom is shared with the adjacent cube and thus each unit cell contains four atoms. *Austenitic steels* have this structure. (See ALLOTROPY and SPACE LATTICE.)

Facets. The flat surfaces of a crystal. In metallurgy, the term is generally applied to the bright crystal faces observed in a fracture.

Facing. (*a*) A coating of any material applied in a wet or dry condition to the face of a mould or core with the object of ensuring a smooth surface on the resultant casting. (*b*) (See HARD FACING.)

Facing Sand. Any special sand mixture placed against the pattern to give certain desired properties to the face of the mould. (A. 26.)

Factice. (*Factis.*) Rubber substitutes prepared by vulcanizing vegetable oils.

Factis. (See FACTICE.)

Factor of Safety. The factor used by the designer to take into account any unknown factor included in his calculations.

Faggot. The small bars of *blister steel* which were welded together under the hammer in the manufacture of *shear steel*.

Fagot. (See FAGOTING.)

Fagoting. The making of a *fagot* or box, the bottom and sides of which are formed of *muck* or scrap bars and the interior of miscellaneous iron scrap or a mixture of iron and steel scrap. (A. 28.)

FAH Cast Irons. Synthetic irons produced by recarburization of molten steel in the basic *converter*; they were originally made at the Hagondange Steelworks. Two converters are used, one to convert pig iron into steel, and the other for the recarburization of this steel. (M. 69.)

Fahrenheit, Gabriel Daniel. (1686–1736.) A German physicist and the inventor of the *Fahrenheit Scale*.

Fahrenheit Scale. A temperature scale in which the melting point of ice is taken as 32°, and the boiling point of water, under an atmospheric pressure of 760 mm., as 212°. 9 Fahrenheit degrees = 5 *Centigrade* degrees. Degrees F are converted to degrees C by subtracting 32 from the Fahrenheit value, multiplying by 5 and dividing by 9. Degrees C are converted to degrees F by multiplying by 9, dividing by 5, and adding 32 to the result. (For Temperature Conversion Table, see Appendix I.)

FAKRA. Fachnormenausschuss der Kraftfahrzeug Industrie (The Standardization Organization of the German Automobile Industry).

Fall. (See AFTER BLOW.)

Falling Blast Furnace Slags. Slags which disintegrate into a coarse powder after cooling from the molten state. (P. 5.)

Falling Seam. An American term for a defect in butt-welded tubes; it takes the form of a depression along the weld on the outside of the tube.

Falling Weight Test. A test in which a specified weight is dropped from a specified height on to the part under test. The test is commonly applied to such parts as rails, axles and tyres, when a maximum deflection without fracture is specified.

False Brinelling. (See FRETTING CORROSION.)

False Cheek. A body of sand in a *mould*, occupying the same position and performing the same functions as a *cheek* but contained within the *cope* and *drag*, although separate from them. (P. 1.)

False Cope. A temporary *cope* used only in forming the parting and, therefore, not part of the finished *mould*. (A. 26.)

False Core. That part of a *mould* which is so made that it can be taken out in order to facilitate the removal of the *pattern* from the sand.

Family. (*a*) The planes in any one crystal that have common indices. (*b*) A group of chemical elements having allied properties, e.g. the *halogens*.

Fan. An arrangement whereby air is supplied under pressure to effect the combustion of coke in the *cupola*.

Fanning. A method by which a *blast furnace* is kept in operation on a very much reduced wind volume. The practice can be continued indefinitely with greatly reduced fuel consumption and output, and yet can be quickly brought back to normal production. (B. 116.)

Fantini Process. A method of rust-proofing iron and steel articles by immersion in a bath composed of a solution of chromic acid or of a salt thereof, to which has been added a sulphur compound which produces colloidal sulphur on reacting with the solution. (F. 3.)

F.A.O. *Finish all over.*

Farad. The unit of electrical capacity. The capacity of a condenser which, when charged to a potential of one *volt*, carries a charge of one *coulomb*.

Faraday, Michael, F.R.S. (1791–1867.) An English chemist and physicist who discovered the laws of electro-magnetic induction and first produced electrical motive power in 1831. He carried out systematic investigation on an extensive series of alloys of iron, thus laying the foundation for the alloy steels of to-day.

Faraday's Laws. (*a*) A principle arising from Faraday's discovery of electro-magnetic induction. It states that the induced e.m.f. in any circuit is proportional to the rate of change of the number of lines of force linked with the circuit. (*b*) The amount of chemical change produced by a current is proportional to the quantity of electricity passed. (*c*) The amounts of different substances liberated or deposited by a given quantity of electricity are proportional to the chemical equivalent weights of those substances.

Farmer Fatigue Testing Machine. A rotating beam type of machine, producing a complete reversal of stress during each cycle and a uniform bending moment on the specimen. It has a speed of testing of approximately 3500 cycles per minute.

F.A.S. Free alongside ship. A term indicating that the loading, and expenses incurred therein, of goods so quoted are the responsibility of the purchaser.

Fash. (See BURR.)

Fat Sand. A term used in the foundry to describe a sand having a high clay content.

Fatigue. The deterioration of the mechanical properties of a metal under repeated cycles of stress. Fracture results from the development of a crack which progresses across the section, with time and repeated stress. (See also FATIGUE LIMIT, CORROSION FATIGUE and STRESS RAISERS.)

Fatigue Crack, *Failure or Fracture.* A fracture starting from a nucleus, often under conditions of fluctuating loading, and spreading through the metal. It is assumed that such cracks are the result of the work hardening of the slip planes of the metal crystals under repeated stress. A typical fatigue crack shows two zones, firstly a brightly polished zone which has been smoothed by the repeated opening and closing of the crack, and secondly a rough crystalline surface which represents the final sudden failure of the small area of sound metal not reached by the fatigue crack when failure occurred. (M. 158.)

Fatigue Curve. (See S-N DIAGRAM.)

Fatigue Failure. (See FATIGUE CRACK.)

Fatigue Fracture. (See FATIGUE CRACK.)

Fatigue Limit. The highest stress, in tons per sq. in., that can be applied and reversed continually without bringing about fracture within a specified very large number of alternations.

Fatigue Range. The maximum range of stress which a metal will withstand indefinitely. When the *maximum stress* in tension equals that in compression, the fatigue range is twice the *fatigue limit*. The mean stress, i.e. half the range, must be stated to define the fatigue conditions.

Fatigue Ratio. The ratio of the fatigue strength to the maximum tensile strength.

Fatigue Test. A method of determining the behaviour of metals under repeated applications of stress. Normally failure occurs at a much lower value of repeated stress than that of the maximum stress under static tensile stress.

Faxfilm Process. A method for surface flaw detection in which an exact reverse replica of a test surface is quickly made in clear plastic. Projection of this replica in a microprojector provides a magnified representation of the surface, with marked three-dimensional effect. (I. 13.)

Fayalite. A mineral, ferrous orthosilicate (Fe_2SiO_4).

Faying Surfaces. The surfaces of a lap joint which are in contact.

F.B.I. Federation of British Industries. (See Appendix V.)

F.C. Abbreviation for Furnace Cooled. (See FURNACE COOLING.)

F.C.C. Face Centred Cubic.

Fe. Chemical symbol for *iron*, from the latin *ferrum*.

Feather Ends. Firebricks with tapered ends.

Fe_2CO_3. Chemical formula for iron carbonate.

Feed. (*a*) The rate at which the cutter of a machine tool is advanced in a machining operation. (*b*) The raw material supplied to a process. (*c*) The mechanism for advancing material into a machine for processing.

Feed Hopper. A term used in *powder metallurgy* for a container used in storing the powder prior to compacting in a press. (G. 30.)

Feed Lines. Lines left on work by incorrect action in machine grinding.

Feed Pipe. The pipe through which water is led into a boiler.

Feed Shoe. A term used in powder metallurgy for a member of a press connecting the *feed hopper* and the *die cavity* which has a channel or hole through which the powder flows by gravity or vibration. (G. 30.)

Feed Water Heater Tubes. Tubes in which water is heated before it passes into the boiler.

Feeder. (See FEEDING HEAD.)

Feeder Head. (*Hot Top.*) (*Sinkhead.*) (*Shrinkhead.*) The refractory head, made, for example, of *silica bricks*, *ganister* or fireclay, placed on the top of the ingot mould with the sole object of decreasing the extent of the primary *pipe*. The lower thermal conductivity of the refractory lining of the feeder-head, compared with that of the cast iron mould walls, serves to maintain the steel in a molten condition in the feeder head for a considerably longer time than that in the mould. By this means, a reservoir of molten steel is maintained which serves to fill the contraction cavity that would otherwise be formed in the ingot. The purpose of the arrangement is to confine the pipe within the feeder head and thus to increase the proportion of usable material. (G. 49.)

Feedex. An exothermic feeding compound supplied as a dry powder, and prepared by mixing with water, moulding into the desired shape, and baking at 200° C. When the metal rising in the *mould* reaches the Feedex shape (for example, a sleeve in the riser) the shape is ignited and the resulting exothermic action produces a temperature up to 2000° C. Most of this heat is transmitted to the metal and an actual increase in the metal temperature results. (L. 14.)

Feeding. (*a*) Supplying hot metal to the *feeder head* of an *ingot mould* or to the *riser* or *feeding head* in a casting to prevent the formation of shrinkage cavities as the metal contracts on cooling. (*b*) Adding ore to the molten bath.

Feeding Fluxes. Agents of widely varying composition used for covering the surface of the hot metal in runners and risers in order to retain the heat and thus allow the hot metal to feed into the mould cavity to compensate for the shrinkage of the casting as it cools. Feeding fluxes range from ordinary moulding sands to the more complex, specially prepared, proprietary brands.

Feeding Head. (*Shrink Head.*) In the foundry, a large *riser* containing a sufficient body of metal to act as a *feeder* as the metal of a *casting* contracts on solidification, thus preventing voids in the casting.

Feeding Rod. An iron rod which is pushed down the *feeder* into the mould to break up any pockets of gas which may have formed and thus assist its escape, and to promote the flow of hot metal into the mould.

F.E.F. Foundry Educational Foundation. (U.S.A.)

Feldspar. An alternative spelling of *felspar*.

Felspar. A term applied to a group of minerals consisting essentially of silicates of aluminium together with either potassium, sodium or calcium and, rarely, barium, whilst magnesium and iron are always absent. The hardness of these minerals, which constitute a considerable portion of the earth's crust, varies between 6 and 6·5 *Moh's scale*. (D. 4.)

FeO. Chemical formula for ferrous oxide.

Fe_2O_3. Chemical formula for *ferric oxide*.

Fe_3O_4. Chemical formula for *ferrosoferric oxide*, magnetic oxide of iron.

Fe_3P. Chemical formula for iron phosphide.

Feran Process. A method, developed in Germany, for the cladding of steel, in which aluminium sheet containing about 0·7% silicon is rolled on to a very low carbon steel at a temperature of about 200° C., by a sticking pass of 40% reduction.

Ferberite. A mineral consisting of ferrous tungstate ($FeWO_4$). It usually contains a small amount of manganese.

Ferghanite. ($U_3(VO_4)_2 \cdot 6H_2O$.) A vanadium ore.

Fergusonite. A mineral which is essentially a metaniobate (and tantalate) of *yttrium* with *erbium, cerium, uranium, iron* and *calcium*, etc., in varying amounts. (D. 4.)

Fernandinite. ($CaO.V_2O_5.5V_2O_5.14H_2O$.) A vanadium ore.

Ferramics. Magnetic ferrites which have extremely high volume-resistivity, the entire effect of air-gap being eliminated from them. They are applied in the television industry, and in the magnetic tape recording field, etc. (S. 12.)

Ferranti Furnace. An induction furnace in which the primary coil induces a current in a bath of metal which replaces the secondary winding.

Ferri. A prefix from the Latin *ferrum* meaning iron.

Ferric. A term for iron salts in which the iron is in the *trivalent* condition.

Ferric Blast Furnace. A modified type of blast furnace employing coal as fuel, the coal being converted to coke in the upper part of the furnace.

Ferric Oxide. (Fe_2O_3.) An oxide of iron occurring in nature, for example, as *haematite*.

Ferriferous. Containing iron.

Ferrite. (*a*) A term once restricted to pure *alpha iron* but now extended to include any solid solutions of which alpha iron, as distinct from *gamma iron*, is the solvent. It forms from the gamma (austenitic) phase, in slowly cooled *hypo-eutectoid steels*, and unless hardened by cold work it is soft and ductile. It may contain, in solid solution, many of the special elements, e.g. up to 30% chromium, or 15% silicon, but very little carbon, i.e. less than 0·03%. Pure iron consists of 100% ferrite and ferrite is the principal constituent in low carbon steels. When etched with nital, the grain boundaries appear as dark lines surrounding the white ferrite. (See Plates VII (a), (b) and VIII (a), (b) and (c). (*b*) The name proposed by Vogelsang for the amorphous hydroxide of iron, which in red or yellow particles plays an important part in many rocks, and whose composition is as yet undetermined.

Ferrite Ghost. (See GHOST.)

Ferritic Stainless Steels. (See FERRITIC STEELS.)

Ferritic Steels. Steels which, owing to the presence of high percentages of alloying elements such as chromium and silicon, do not form *austenite* on heating, e.g. *ferritic stainless steels* containing about 16% to 30% chromium with about 0·1% carbon, which do not harden appreciably on heat treatment but are liable to become brittle on exposure to elevated temperatures. (See also CORROSION RESISTING STEELS.)

Ferritizer. A term applied to an element which, when added to steel, promotes the formation of *ferrite*.

Ferro. A prefix from the Latin ferrum, meaning iron.

Ferro Alloys. A term used for alloys of iron with another metal such as chromium, manganese, silicon, tungsten, molybdenum or vanadium. These alloys are used as a means of introducing the alloying element into steel or cast iron, or as deoxidizers. Ferro alloys are usually produced by electric smelting, an exception being high carbon ferro manganese which is normally produced in *blast furnaces*.

Ferro Aluminium. An alloy of iron and aluminium used in steelmaking as a *deoxidizer*, or in the foundry for adding aluminium to steel, or adding iron to aluminium alloys. Two commercial grades contain 20% and 50% of iron respectively, the remainder being aluminium. The first grade melts at 1040° C., and the second at 1150° C. With 50% of aluminium, the alloy is extremely brittle and breaks into pieces.

Ferro-Bet. A method of treating the surfaces of steel structures which cannot be dipped in a bath. This consists of brushing off loose rust and painting or spraying on a phosphatizing solution, which forms a fine crystalline layer of complex phosphates on the steel, preventing rust formation and giving good adhesion to subsequent paint coating.

Ferro Boron. An alloy of iron with 10% to 25% of boron, up to 1·5% silicon and 0·5% aluminium. It is used to introduce *boron* into malleable iron, steel and some aluminium alloys. As boron is rapidly oxidized, ferro boron is added only to completely oxidized steel and should be the last addition made to the ladle.

Ferro Chromium. An iron alloy containing about 60% to 75% chromium

and up to 10% carbon. It is made by the reduction of chrome ore either by carbon or silicon in an electric furnace or by means of the *thermit process.* It is the most widely used medium for the introduction of chromium into the steel bath, and is divided into two classes: high carbon and low carbon. The high carbon grades contain from 4% to 10% carbon and up to 3% silicon, whilst the low carbon grades range from 2% down to less than 0·03% carbon, the latter type being known commercially as "carbon free". The "carbon free" grade is of critical importance in the manufacture of the austenitic chromium-nickel corrosion-resisting steels of the 18/8 type, where a higher carbon content under certain conditions of service may lead to failure by *intercrystalline corrosion.* (O. 18.)

Ferro Coke Process. In this process, coal of suitable type and size is blended with finely-crushed iron ore or fine-ore concentrates and carbonized in the usual way. The resulting coke contains metallic iron and is used in the blast furnace as part of the normal burden. (C. 18a.)

Ferro Columbium. (See FERRO NIOBIUM.)

Ferro Concrete. *Reinforced Concrete.* (See CONCRETE.)

Ferro Manganese. The form in which manganese is generally used in the steel industry. The ordinary qualities contain 70% to 80% manganese and about 7% carbon. *Spiegeleisen* may contain from 12% to 30% manganese and about 5% carbon. These alloys are produced in small blast furnaces of standard type except that they are often fitted with special cooling devices, owing to the high temperatures involved in the reduction of manganese oxides. Ferro manganese is usually sold in lumps. Low carbon ferro manganese is an electric furnace product and is available in several grades, of which the highest quality may contain as much as 90% manganese with a maximum carbon content of 0·07%. (O. 18.)

Ferro Molybdenum. An iron alloy usually containing about 50% to 60% molybdenum. It is manufactured in the electric furnace from molybdenite, sodium molybdate, calcium molybdate, or molybdic acid, the reducing agent employed being carbon or ferro silicon. In the production of steels with a molybdenum content of less than 1% molybdic oxide, or calcium molybdate have largely replaced ferro molybdenum as additional reagents, as these materials are less expensive and have the added advantage that they do not raise the carbon content of the resulting steel. For the production of steels containing more than 1% molybdenum, however, some manufacturers prefer to use ferro molybdenum, which is added to the bath well before tapping, to ensure complete solution.

Ferro Nickel Alloys. Alloys of iron and nickel. The alloys are characterized by the fact that as the nickel content approaches 36% the coefficient of thermal expansivity decreases rapidly; with still higher nickel contents the thermal expansion again increases, at first slowly and then more rapidly to that of pure nickel. Ferro nickel alloys are not to be confused with other alloys bearing the prefix ferro, i.e. *ferro alloys*, as they do not function as steelmaking additions, i.e. for the introduction of nickel into the bath during the course of its manufacture.

Ferro Niobium. (*Ferro Columbium.*) An iron alloy containing 50% to 60% niobium with up to 8% silicon and 0·4% carbon. It is the form in which niobium is added to the molten steel bath, and for the production of this alloy niobium containing ores are concentrated and reduced by silicon in an electric furnace.

Ferro Selenium. An alloy employed for adding selenium to steels to give *free machining* properties. A typical example contains carbon 0·90%, silicon 0·72%, sulphur 0·22%, phosphorus 0·20%, selenium 52·11%.

Ferro Silicon. An alloy of iron with silicon contents varying from 15% to 95%. The alloy is produced in a specially constructed electric furnace, the smelting process being relatively simple. Above 1500° C., quartz is reduced by carbon to silicon which dissolves in iron to form ferro silicon. The alloy is tapped at regular intervals and cast in sand beds. In order to obtain a dense, clean product, it may also be cast into slowly rotating, water-cooled copper pans. There is no slag formed, except for crusts which accumulate around the electrodes and must be removed periodically. Some silicon is vapourized and lost in the furnace gases. Since any metallic impurity goes into the metal with nearly 100% recovery, the raw materials must be chosen carefully. The quartz is usually 99% SiO_2 or above, with as little alumina as possible. Coke and anthracite are used for grades up to 50% silicon; for higher grades, an addition of charcoal is advisable in order to open up the furnace. For silicon metal, petroleum coke is required. The iron is added in the form of steel scrap; iron ore may also be used, but this consumes more furnace power. (A. 1.)

Ferro Silicon Aluminium. An alloy containing about 45% silicon, 12% to 15% aluminium and the remainder iron. It is used as a deoxidizer in steelmaking and is usually added to the ladle.

Ferro Silicon Chrome. An alloy of iron with 50% to 54% chromium, about 30% silicon and less than 1·2% carbon. It is used for adding chromium and silicon to steels containing less than 2% chromium.

Ferro Steel. Grey cast iron produced by melting together pig iron, cast iron and steel scrap with or without alloy additions.

Ferro Tantalum. An alloy of iron containing about 70% to 80% tantalum, with which is usually associated some niobium and traces of tin, manganese and other metals. It is produced by silicon reduction in the electric furnace.

Ferro Tantalum Niobium. A stabilizer, used to supplement ferro niobium in austenitic chromium-nickel stainless steels. It is also used in high temperature alloys. It contains approximately 40% niobium, 20% tantalum (60% min. niobium + tantalum), silicon 4% to 6%, and carbon ·30% max.

Ferro Titanium. An alloy of iron and titanium, prepared directly by adding the titanium ore to a molten mass of iron and aluminium or ferro silicon. In another method the thermit process is employed to reduce a mixture of one part of titanium oxide with several parts of iron oxide. Ferro titanium is marketed in several grades. The high carbon quality contains about 15% titanium and 6% to 8% carbon. Medium carbon ferro titanium contains 17% to 20% titanium and 3% to 5% carbon. The low carbon alloy is made in several grades in which the titanium ranges from about 20% to 45% with a maximum carbon content of 0·10%. All the above grades contain an appreciable quantity of aluminium and silicon which together may vary from about 3% in the high carbon alloys to as much as 7% with low carbon. In high carbon killed steels, ferro titanium is used as a final deoxidizer to prevent the occurrence of segregation and of objectionable inclusions and for controlling grain size.

Ferro Tungsten. An alloy generally made by the direct reduction of tungsten ore, usually *wolframite*, by carbon, but it may also be produced by incorporating a specified amount of wolframite with iron oxide or steel scrap in the electric furnace. The tungsten and iron are then charged with charcoal, glass and quartz or other flux and smelted at high temperatures, the ferro tungsten collecting at the bottom of the furnace. Owing to its high melting point, ferro tungsten cannot be tapped and the solid *button* of ferro tungsten, weighing about 6 tons, has to be taken from the cold furnace and broken into pieces which are crushed and marketed in sizes of 1 in. to ⅜ in. and ⅜ in. and under. There are various grades of ferro tungsten with carbon contents of up to 2·5% but the standard quality contains 70% to 80% tungsten with a maximum of 0·60% carbon. (O. 18.)

Ferro Uranium. The uranium content of these alloys may vary from 30% to 85%. A typical example contains carbon 5·46%, silicon 1.56%, vanadium 1·38% and uranium 50·75%.

Ferro Vanadium. The form in which vanadium is usually added to steel. There are several grades varying in composition from 35% to 55% vanadium, 1·5% to 2% silicon and 0·2% to 3·5% carbon. (O. 18.)

Ferro Zirconium. An alloy of iron containing from about 20% to 40% zirconium and appreciable quantities of silicon. It is used as a steelmaking addition. (See ZIRCONIUM.)

Ferroferrite. The name suggested by *Stead* for a constituent consisting essentially of pure iron. He further suggested that when iron is associated with large quantities of an element with which it forms solutions such as phosphorus, nickel, aluminium, manganese, silicon, chromium and vanadium, the constituents so formed should be known as *phosphoferrite*, *nickelferrite*, *aluminoferrite*, *manganoferrite*, *silicoferrite*, *chromoferrite* and *vanadoferrite*.

Ferrograph. (*a*) A permanent record of a magnetic pattern made by coating the surface of the specimen with cellulose acetate varnish which strips off when dry. A volatile solvent is added to the magnetic fluid before spraying. A typical solution consists of amyl acetate 700 ml., ethyl alcohol 300 ml., celluloid 25 gm., and crocus powder (iron oxide) 25 gm. (T. 18.) (*b*) An instrument for the rapid identification of steels. It depends on the principle that the magnetic properties of steel vary with composition and it employs an oscilloscope tube as indicator. (Cf. FERROGRAPHY.)

Ferrography. This process enables graphic information to be recorded on magnetic materials and to be reproduced on paper in visual form. Black and white and colour reproductions are possible. The image is received by a photo-cell and the signal used to modulate a carrier wave. The resulting signal is fed to a recording head similar to that used for audio-magnetic recording. 100

lines per inch give the minimum resolution and 400 lines per inch the maximum economic resolution. The magnetic matrix can be stored indefinitely and can be used for multiple printing. The advantages of the process are economy and speed of operation, permanence of image, and the ability to record any facsimile transmission, or scanned images. (Cf. FERROGRAPH.) (A. 57.)

Ferrolene. A town gas enriched by a patented process. (E. 22.)

Ferromagnetic Ceramic Materials. A mixture of crystals of iron oxide with various other metallic oxides (not metals). Their general chemical formula is $MOFe_2O_6$, where M stands for a divalent metal such as magnesium, nickel or zinc. No metals in metallic form and no organic compounds are contained in the ferrite material. The ferrite is a uniform, solid body similar in texture and mechanical properties to other oxides or silicate bodies. The high volume resistivity, coupled with high permeability, constitutes one of the main advantages of the material over either iron dust or all-metallic core materials. The high volume resistivity keeps eddy-current losses to negligible values and permits the use of solid cores with alternating magnetic fields. (G. 33.)

Ferromagnetic Material. A material possessing *ferromagnetism*.

Ferromagnetic Testing. A comparative method for determining the approximate carbon content of a steel based on the principle that when an energized coil is placed within a secondary coil with a steel tube between them the coupling between the coils will vary with the characteristics of the steel. In practice, two sets of coils are used; one with a standard steel specimen of known carbon content, whilst the unknown is placed in the second set. The coils are connected in opposition, and the resultant voltage is applied to a detecting instrument incorporating a cathode-ray indicator. (J. 1.)

Ferromagnetism. The property of materials, e.g. iron, steel, nickel and cobalt, of being attracted by a magnet. Such metals and alloys have a *permeability* considerably higher than unity and which varies with the *flux density*.

Ferromagnetography. A method through which printed and written text and pictures are reproduced by first forming magnetic images on thin sheets of permanent-magnetic material and then making these images visible by the deposition of ferromagnetic particles. The latter particles are then transferred to a medium such as paper. (E. 75.)

Ferrometer. An apparatus for determining the relative amounts of ferrite in steels with duplex structures, e.g. austenitic steels with free ferrite, by measuring the magnetic and electrical properties of the material. The steel specimen is used as a core in a testing coil forming part of a system which operates in the same way as a transformer working on no-load. The primary winding is fed with a 50 cps current of constant amplitude. The secondary voltage depends on the core material. The two voltage components of the secondary voltage indicate the apparent permeability of the steel and its eddy-current losses. Both quantities can be indicated by direct reading instruments. (S. 82.)

Ferron. A product, obtained from the treatment of spent pickling liquor, which is claimed to form a very useful building material with excellent heat-resisting and acoustic properties. (R. 13.)

Ferropouls. A magnetic crack detector similar in principle to *magnaflux*.

Ferroscope. A hardness testing instrument. The operating principle is based on the fact that the mechanical properties of steel are closely related to their magnetic hysteresis, visual indications of the properties, as compared with those of a standard sample, being obtained. (A. 11.)

Ferrosoferric Oxide. (Fe_3O_4.) Magnetic oxide of iron. It occurs in nature as black octahedral crystals. (See MAGNETITE.)

Ferrostan. A method for the electrolytic production of tinplate, in which the electrolyte consists of a solution of stannous sulphate in an aqueous solution of isomers of phenol sulphonic acid. (T. 15.)

Ferrostatic Pressure. Pressure induced by a head of liquid iron or steel.

Ferrotantalite. A mineral containing iron, tantalum and niobium in widely varying proportions. (See TANTALITE.)

Ferrotemp Pyrometer. A pyrometer for measuring accurately the temperature of molten grey and white iron by means of an immersion thermocouple, $1\frac{1}{8}$ in. outside diam. and 19 in. long. The pyrometer is available in two models, a portable and a stationary type. The temperature scale reads from 870° to 1760° C. The smallest temperature division on the scale is 10°, allowing easy estimation to 5° at a glance. (F. 33.)

Ferrotest. An instrument for the magnetic non-destructive testing of solid

bars, which employs the usual alternating current. The potential generated in a movable secondary coil around the test-piece is opposed by that generated in a similar way on a control specimen. Any fault or variation in the bar being tested gives rise to a potential in the secondary coil, which can be used to deflect a cathode-ray beam, and thus indicate the fault. By choosing suitable phase angles, the sensitivity of the instrument for various types of defect can be increased. (J. 9.)

Ferrous. A term for iron salts in which the iron is in the *divalent* condition.

Ferrous Alloys. Alloys in which the predominant metal is iron.

Ferrous Ammonium Sulphate. ($(FeSO_4).(NH_4)_2SO_4.6H_2O$.) *Mohr's Salt.*

Ferrous Oxide. (FeO.) Oxide of iron.

Ferroxdure. A sintered oxide consisting mainly of the oxide $BaFe_{12}O_{19}$, and used for the production of permanent magnets. (W. 37.)

Ferroxyl Indicator. An aqueous solution containing agar agar 10 g. per litre, sodium chloride 10 g. per litre, potassium ferricyanide 1 g. per litre, phenolthalein, a few drops. By immersing a piece of iron in the reagent it can be used to demonstrate the corrosion occurring on a metal surface. The phenolthalein reacts with the hydroxyl ions to give a pink colouration showing the alkalinity at the cathode portions of the metal surface and the ferricyanide reacts with the iron ions giving a blue colouration where the iron is going into solution at the anode.

Ferroxyl Test. A method of revealing any porosity existing in nonferrous coatings over a ferrous base, for example in tinned plate, using the *ferroxyl indicator.*

Ferruginous. Containing iron.

Ferrum. The Latin name for iron, from which is derived the symbol *Fe.*

Fervanite. ($2Fe_2O_3.2V_2O_5.5H_2O$.) A vanadium ore.

Féry Radiation Pyrometer. An instrument in which the heat radiated from the hot body is focused, by means of a concave mirror, on to a small central hole behind which a small thermocouple is placed in front of two small, inclined, mirrors. The instrument is sighted on to the hot body and focused by rotating a screw until the lower and upper halves of the image coincide; the e.m.f. generated by the thermocouple is indicated on a galvanometer. The instrument, once focused, gives continuous readings and may be connected to a recording indicator.

Fe_3Si. Chemical formula for iron silicide.

Fescolizing. An electrolytic process of depositing a layer of metal, usually nickel or chromium, on a steel part to enhance corrosion- and wear-resistance, and also to build up worn parts.

Fettler. (*a*) A workman who carries out the operation of *fettling.* (*b*) An Australian term for a railway worker.

Fettling. (*a*) (*Dressing Off*). The removal of adherent sand from *castings* by *hammering, shot blasting, tumbling* or *hydro blast.* (*b*) Repairing the bed of an *open hearth furnace.* (*c*) Oxides used in the *puddling process.* (*d*) The term as used in Australia refers to the attention given to the rail track.

Fiat Furnace. An electric arc furnace consisting of a reinforced cylindrical shell of steel plate, lined with dolomite. The hearth is hemispherical and mounted on two circular shoes of cast steel, which allow of rotation in any direction. There are two openings in the shell, a larger one at the back for charging and slagging, and a smaller one in the front for pouring. The doors closing them are water-cooled and last about 150 heats before needing repair. The roof is silica-lined and both it and the hearth have a life of 120 to 130 heats (in a 5 to 6 ton unit). There are three graphite electrodes (25 cm. diameter in the 5-ton furnace) disposed as in the *Heroult furnace,* and provided with special economizers. The hearth is slightly conductive, and apparently affords the opportunity of operating the furnace in a similar way to the *Newkirk furnace.* (J. 26.)

Fiberfrax. A proprietary ceramic fibre, made by melting aluminium oxide, silica and certain modifiers in an electric furnace and blasting a stream of the molten material with a controlled jet of air or gas. It is of fluffy texture with a density, as produced, of 2 lb. per cu. ft., its outstanding properties being resistance to high temperature (up to 1260° C.), light weight, low heat transfer characteristics, excellent electrical properties, and good filtering efficiency. When packed to a density of 6 lb. per cu. ft. it is claimed to be a better insulating medium for electric furnaces than high quality cemented refractory bricks. Its thermal conductivity is of the same order as that of glass fibre, but it retains its properties to much higher temperatures.

Fibre. (See FLOW LINES.)

Fibre Axis. (See FIBRING.)

Fibre Diagram. An X-ray diffraction pattern, or a chart prepared therefrom, showing the existence of fibring or measuring its completeness. (A. 27.)

Fibre Stress. Local stress at a point or line on a section over which stress is not uniform, such as on the cross-section of a beam under a bending load. (A. 27.)

Fibring. The state of a crystalline aggregate in which the preferred orientations are obtained by rotation about a line, the *fibre axis*. If fibring is complete, all azimuths about the fibre axis are equally probable. If fibring is incomplete, the preferred orientations may decrease to a small number and the concept of fibring loses its value. Besides simple fibring there may be a helical fibring in which the fibre axis has all the orientations assumed by the tangent to a helix of constant pitch. In ring fibring, the pitch of the helix is zero. (A. 27.)

Fibrous Fracture. (See FRACTURE.)

F.I.D. Federation Internationale de Documentation.' (See Appendix V.)

Field Strength. (See MAGNETIC FIELD STRENGTH.)

Fifty Fifty Practice. Charging an open hearth furnace with approximately 50% pig iron and 50% scrap.

Figures of Merit. (See QUALITY VALUES.)

Filament. Electrical conducting material in the form of fine wire. The material employed usually possesses high electrical resistance, and is thus raised to a high temperature when sufficient current is forced through it.

Filament Wire. Produced chiefly from tungsten and molybdenum. In tungsten production, material in powder form is first fabricated into ⅝ in. sq. 16 in. length ingots by the *powder metallurgy* process. The ingots are then swaged at a temperature of 1500° C. to approximately 0·068 in., and reduced further by hot drawing to extremely fine sizes. Molybdenum wire production is somewhat similar to tungsten processing, and alloyed with tungsten it has a wide application in various units essential to radio valve production.

File Making. High carbon steel containing 1·2% to 1·3% carbon is rolled into bars of the required section and cut into suitable lengths. The lengths are then tanged and forged or *mooded* to the required shape. These forged file blanks are then annealed at 750° to 780° C. after which the scale is removed by grinding. They are then immersed in lime water, and afterwards stored until they can be *cut*. After cutting, they are hardened by heating to 760° to 780° C., and quenching in a saturated brine solution. The files are withdrawn from the quenching bath whilst still too warm to handle, and whilst in this condition they are straightened if warped. They are then subjected to a mud spray or hand-scrubbed to remove any foreign matter and dipped in oil. The tangs are then softened by dipping in molten lead, after which they are coated with vaseline, and the finished files sent for inspection.

File Prover. A piece of steel, usually of about 475 Brinell hardness (550 for saw files). It is used to test the cutting quality of files. (See PROVER TEST.)

File Scratch Test. A test for estimating surface hardness. The use of 8 in. square taper files, tempered to give a hardness range between 65 and 25 Rockwell C, is recommended; the file ends are ground to needle points. (H. 11.)

Files. Steel hand tools, of various shapes and lengths, into the surface of which teeth of various forms and degrees of fineness are cut. (See CUT.)

Filiform Corrosion. A type of underfilm attack sometimes found with lacquered steel surfaces in atmospheres containing acetic acid and water vapour. The hair-like corrosion tracks may vary in thickness, each being practically constant throughout its length. The length of the tracks is usually several hundred times their width. (S. 44.)

Fillerarc Welding Process. A consumable electrode gas-shielded welding process. It employs a gun, a wire feeding unit, and a specially designed welding generator.

Filler Metal. The additional metal supplied to the weld pool in a fusion welding process to form, on solidification, the *weld seam*. It may be supplied by a *filler rod* of suitable composition which is melted continuously or, in the case of a consumable electrode, the electrode itself may comprise the filler rod.

Filler Rod. (See FILLER METAL.)

Filler Sand. (See BACKING SAND.)

Fillet. (*a*) A concave junction of two (usually perpendicular) surfaces. (*b*) Radii imparted to inside meeting surfaces to give increased strength at their intersection as, for example, the radii of the impressions in forging dies.

Fillet Weld. A weld of approximately triangular cross-section joining two surfaces approximately at right angles to each other in a lap joint, tee joint or corner joint. (A. 37.)

Fillet Weld Inspection Test. In this test a fillet weld is made between two small plates of the material, using the same electrodes and welding procedures as used in the structure from which the specimens are taken. The test plates are then separated by fracturing along the weld, and the welded surfaces thus exposed inspected for the presence of unsoundness or lack of penetration.

Film. A thin, not necessarily visible, layer of material.

Film Test. A rough method of estimating the temperature of molten steel based on the time taken for the formation of a film of solid metal on the spoon sample.

Filter. (*a*) An apparatus used for the separation of solids from liquids, the liquids passing through whilst the insoluble, or solid matter is retained in the filter. (*b*) (For X-rays). A sheet of material that selectively absorbs secondary or other undesired X-rays. (See also BALANCED FILTERS.)

Filtrate. The liquid which has passed through a filter.

Fin. (See FLASH.)

Fin Cracks. Cracks caused by restriction of the ingot during cooling, where *fins* have been formed on the ingot due to the use of a badly cracked *mould*.

Fin Cutting. The removal of internal *fin* from an electrically welded tube.

Fine Silt. Very fine sand particles less than 20 microns in diameter (0·02 mm. or 0·0008 in.). This is included in *A.F.A. Clay* and by itself has very little plasticity or stickiness when wet. (A. 26.)

Fine Silver. Silver of 99·9% purity.

Fine Solder. An alloy consisting of 2 parts of tin and 1 part of lead.

Finery. (*Lancashire Hearth.*) A charcoal hearth into which *pig iron*, having been melted and partially refined in one fire, was run and further refined to convert it to wrought iron by the Lancashire hearth process. (A. 25.)

Fines. (*a*) That portion of a sieved material which passes through the mesh. (*b*) In *powder metallurgy*, that portion of a powder composed of particles which are smaller than a specified size, currently less than 44 microns. (*c*) A term, the meaning of which varies with the type of foundry or the type of work. It refers to those sand grain sizes substantially smaller than the predominating grain size.

Finger Gates. Runner systems, employed in *casting*, to distribute the liquid metal into a mould in a horizontal plane over a wide area. They consist of a normal down-gate leading into a main channel from the base of four finger gates leading into the *mould* cavity. (T. 8.)

Fingernailing. Irregular crescent-shaped ripples sometimes found on the surface of metal which has been deposited by the *shielded arc welding* process. It may be due to any one of several causes, e.g. incorrect position of the electrode during welding or inhomogeneity of the composition of the electrode coating.

Finish. The surface condition of a steel or other material after final treatment such as *cold rolling*, *machining* or *polishing*.

Finish All Over. An instruction on a drawing that the forging in question must have sufficient size over the dimensions given on the drawing to permit all surfaces to be machined.

Finish Annealing. The thermal treatment applied after cold forming operations. It is used when it is desired to remove the stresses induced by cold working or to retain the smooth surface produced by cold drawing.

Finish Mark. A symbol in the form of an *f*, appearing on the line of a drawing, that represents the edge of the surface of the casting to be machine finished. (A. 26.)

Finished Steel. Steel that is ready for the market without further work or treatment. *Blooms*, *billets*, *slabs*, *sheet*, *bars*, and *wire rods* are termed *semi-finished*. (A. 27.)

Finisher. A *die* for making the final impression in forging an article. (A. 27.)

Finishing. (*a*) Processes for smoothing metal surfaces. These operations include *grinding*, *polishing*, *buffing*, *cold rolling* and *cold drawing*. (*b*) (See FINISHINGS).

Finishing Die. The last *die* on a wire drawing machine.

Finishing Materials. (See FINISHINGS.)

Finishing Mill. A rolling mill in which the finished product is rolled.

Finishing Off. The last stages of the boiling-down period prior to *tapping*.

Finishing Pass. The last pass in the finishing roll or *planishing roll* through which the finished product is rolled.

Finishing Temperature. In a hot working process, the temperature at which mechanical working is completed.

Finishings. The final additions made to molten steel in the furnace or in the ladle to produce the desired composition or to effect deoxidation.

Fink Process. A method of producing a protective aluminium coating on iron or steel by first heating it in a reducing atmosphere, such as hydrogen, at about 730° C., and then immediately immersing it in molten aluminium. (E. 63.)

Finotest. A hardness tester for small loads. It works with a diamond pyramid with an angle of 136°, according to the *Vickers* method, but it is also possible to use indenters of the *Knoop* or *Grodzinski* type on this instrument and to carry out scratch tests. The loading device, suitable for loads of 300, 500, 1000, 1500, 2000, 2500, 3000 and up to 10,000 grams, is designed in such a way that the weight acts directly on the indenter. An adjustable oil damping device is provided to ensure correct loading, free from vibration. A microscope provides magnifications of up to

400. It is claimed that the measuring device can give readings to 0·0005 mm. (M. 139.)

Finsider. Financial Siderurgical Industry: the Government financial group which controls the nationalized Italian ferrous industry.

Finsider Process. The treatment of molten cast iron by submerging in it compacts consisting of chips of magnesium or of Elektron scrap. The compacts are prepared by ramming the chips into the perforated head of a plunger, which is immersed in the iron. The magnesium vapour so generated issues from the perforations and bubbles through the iron, treating it safely and without explosive effects. (L. 45.)

Fir Tree. (See DENDRITE.)

Fir Tree Centrifugal Casting. (See CENTRISPINNING.)

Fir Tree Crystals. (See DENDRITE.)

Fire Cracking. (*a*) Cracking due to the too rapid heating of severely stressed metals as, for example, metals which have been submitted to *deep drawing.* (*b*) (See FIRECRACKS).

Fire Hole. (See CRUCIBLE PROCESS.)

Fire Waste. (*Heat Waste.*) Loss of material caused by the oxidation of the surface, and subsequent scaling, during hot working.

Firebox Quality. An American term for plates for pressure vessels which are to be exposed to fire or heat whilst under mechanical stresses.

Firebrick. A brick made from highly *refractory* clays, which in the fired state consists essentially of silica and alumina.

Fireclay. The term is applied to any clays having a fusion point of more than approximately 1600° C. and which can, therefore, be used as a refractory. Such clays are widely distributed and vary very considerably in their characteristics. They consist essentially of silica and alumina. An essential feature of their composition is that they should contain little or no alkali content as this tends to act as a flux, thus lowering their melting point.

Firecoat. A term sometimes used for oxide coating on metal, produced by heating or by direct contact with a flame.

Firecracker Welding. (*Elin-Hafergut Verfahren.*) (*EHV.*) In this process, an electrode covered with suitable fusible insulating covering is laid along the whole length of the joint, the insulation being of such a thickness that the electrode is held at the right distance from the work. One end of the electrode is exposed. The arc is struck between the electrode and work and slowly travels along the joint. The insulation, formed of asbestos smeared with sodium silicate, aluminium silicate or the like, fuses and forms a flux. Unless special precautions are observed, however, the firecracker process is difficult to apply. In the Hafergut method it is claimed that all disadvantages disappear if a suitably shaped bar of copper is placed over the electrode, and a strip of any sort of paper is inserted to separate the copper from the base metal and electrode. Spatter is prevented and the short arc, determined by the thickness of the coating, yields the best penetration; the electrode melts in the small space allowed by the bar, combustion of the paper removing oxygen from the welding atmosphere. (S. 112.)

Firecracks. (*a*) Cracks found, for example, on the surface of rolls of hot rolling mills, or metallic bodies which have been subjected to continuous alternating heating by the rolling of hot steel, followed by cooling by water spraying. (*b*) (*Chill Cracks*). Marks on the surface of a hot rolled product which appear periodically, having been produced by a crack or cracks on the surfaces of the roll.

Firestone. A type of refractory rock (*mica schist*) sometimes used for lining furnaces.

Firth Hardometer. The principle embodied in this instrument is similar to that of the *Brinell* machine in which a hard steel ball is pressed, by means of a known load, into the specimen to be tested, the hardness being determined by measurement of the impression. Owing to the limitations of the hardened steel ball, for testing harder materials a pyramid diamond indenter is recommended and can be supplied with the machine, in addition to the hardened steel ball. The hardness numbers are obtained by dividing the load in kilogrammes by the area of the impression in square millimetres; this applies both to the steel ball and to the diamond indenter. In the latter case the hardness numbers obtained should be referred to as the *diamond hardness numbers.* The scale of ball impression diameters and Brinell hardness numbers corresponds exactly to that used with the 10 mm. ball Brinell machine, provided both machines are used with the same ratio of load to square of ball diameter.

Firth, Mark. (See FIRTH, THOMAS.)

Firth, Thomas. (1789–1850.) Thomas Firth, with his eldest son Mark (1819–80) and second son Thomas (1821–60) founded the famous Sheffield firm of Thomas Firth & Sons (now Thos. Firth & John Brown Ltd.), steel manufacturers, in 1842. On the death of his

father, *Mark Firth* became head of the firm, and by 1870 Firth's had become one of the leading steel and gun forging firms in the world.

Firth-Brown Inclusion Count. A method of grading steel samples with reference to the *inclusion* content, in which the examination is carried out on a longitudinal section of bar of convenient diameter divided into ten longitudinal strips of equal width. Four fields in each strip are then examined at a magnification of 130 and graded, the weighted average cleanness of each strip being thereby ascertained. (I. 82.)

Fischer "Iron Library". A metallurgical library founded in commemoration of the 150th anniversary of the iron and steel engineering firm of Georg Fischer, Ltd., Switzerland. (E. 59.)

Fischer-Tropsch Process. A method for converting coal into liquid fuels, i.e. aviation spirit and diesel oils, in which a mixture of carbon monoxide and hydrogen prepared from coke and steam is converted catalytically at low pressure into mixtures of hydrocarbons and oxygenated products. (W. 18.)

Fish Eyes. The brilliant crystalline zone surrounding a hydrogen blowhole. (See also FLAKES.) (Z. 3.)

Fish Mouthing. (See ALLIGATORING.)

Fisher Sub-Sieve Sizer. An apparatus using a gas permeability method for determination of the average particle diameter of powders. A sample, equal in weight (grams) to the true density of the material, is compacted between two porous plugs in a metal tube, to a known porosity. Air or a suitable gas, under a constant pressure head, is passed through the compressed sample and rate of flow measured by a calibrated flowmeter. The average particle diameter of the powder is indicated directly on a self-calculating chart by the liquid height in one arm of the flowmeter tube. No dispersion is required and results are unaffected by particle shape. (G. 48.)

Fishtail. The effect obtained in rolling when the skin or surface of the steel is hotter and elongates more than the middle. A V notch may then develop at the back end of the steel somewhat resembling the tail of a fish. The steel is then said to have *fishtailed*.

Fishtailed. (See FISHTAIL.)

Fitchering. The clogging up of the flutes of a drill by dirt in the hole which is being drilled.

Fitterer Pyrometer. A portable carbon/silicon-carbide thermoelectric instrument of the immersion type, now largely superseded in the United Kingdom by the *Schofield-Grace immersion pyrometer*. (F. 18.)

Fixed Converter. A Bessemer converter which could not be tilted, the blown metal being tapped through a hole in the bottom. The type is now obsolete.

Fixed Metals. A term sometimes given to alkali metal carbonates.

Fixture Quenching. A term employed in the U.S.A. when a part is held by clamps during quenching in order to avoid distortion.

Flake. A piece of steel which has become detached from the surface of, for example, a solid roll as a result of spalling.

Flake Graphite. Graphite in the form of flakes in *cast iron*.

Flake Powder. In powder metallurgy, flat or scale-like particles whose thickness is small compared with the other dimensions. (G. 30.)

Flake Process. A method for galvanizing iron nails. It consists essentially of melting granulated zinc in contact with the nails in a heated rotating drum.

Flakes. (*Snowflakes, Lemon Spots, Hair Line Cracks, Thermal Bursts, Shatter Cracks.*) Fine fissures found lying in all directions in the interior of steel forgings. They occur most frequently in large forgings of alloy steel, but they have been found in carbon steels. Flakes have been noted in the heads of American rails (Shatter Cracks), in tyres and gun forgings. Their occurrence is attributed to the presence of hydrogen in the steel and it has been established that they can be eliminated by retarded cooling of the forgings down to below 100° C.

Flaking. (*a*) The breaking away of particles of the zinc coating from a galvanized surface. (*b*) A splitting-off of a basic refractory brick at a position between 1 and 2 in. behind the hot face, which sometimes occurs as a consequence of flux penetration. (See also SPALLING.)

Flamatic Hardening. (See FLAME HARDENING.)

Flame Annealing. A process in which the surface of an iron-base alloy is softened by localized heat applied by the flame of a high temperature torch. (A. 28.)

Flame Cleaning. Cleaning metal surfaces by the application of a high temperature flame. The operation is frequently used after *sand blasting* in order to remove by oxidation or vaporization any residual organic matter such as oil or wax which may still adhere to the surface of the metal.

Flame Cutting. (*Gas Cutting.*) A process using an oxyacetylene torch with a

central jet of oxygen. The material is locally heated by means of the oxy-acetylene torch, after which the oxygen jet is turned on, rapidly oxidizing the metal in the direct path of the jet. The cutting action is a combination of the chemical and erosive actions of the high velocity jet of oxygen and the process is particularly adapted for steel.

Flame Descaling. The removal of scale from steel by rapid heating of the surface with an oxy-acetylene or other high temperature flame. The heat is merely superficial and the scale tends to flake off due to differential thermal expansion.

Flame Gouging. A special application of the *flame-cutting* process, the main difference being found in the fact that the cutting action does not penetrate the full thickness of the component material, and that it can be limited to any required depth.

Flame Hardening. (*Shorter Process* or *Shorterizing*.) A precision method for local hardening in which the steel is heated to a temperature above the Ac_3 point by a mechanically operated oxy-acetylene blowpipe which traverses the object to be hardened at a pre-determined rate. Quenching is carried out by a jet of water, air or nitrogen which follows immediately behind and is likewise mechanically controlled. The hardened layer may vary in depth from a mere skin to 0·25 in., according to the practice and material being treated. (W. 40.)

Flame Plating. A method of coating metal parts with powdered metals in thicknesses between 0·0005 and 0.020 in. In the operation, the temperature of the base metal does not exceed 200° C., so that the danger of a change in the metal properties or of thermal distortion is insignificant. The process has so far been mainly used with tungsten carbide powder for imparting high hardness and abrasion resistance to surfaces. The tungsten carbide used consists of WC and a few complex tungsten and cobalt carbides, cobalt representing 8% of the total composition. An excellent mechanical interlocking bond is obtained between the parent metal and the coating, in which no dilution of the tungsten carbide takes place whether from the base metal or any other source. The coating can be deposited on practically all base metals, e.g. steels, cast iron, aluminium, copper, etc., and parts made of them will thus combine such properties as good electrical conductivity or light weight with high wear resistance. (W. 31.)

Flame Priming. This process consists of scrubbing steel surfaces with a series of closely spaced oxy-acetylene flames which are of extremely high temperature and velocity. As a result, all mill-scale that is not too tightly bonded is loosened by the sudden thermal expansion. Combined water is expelled from any rust that is present, whilst other contaminants such as oil and acid salts are consumed or disintegrated by the flames. The surface is then scrubbed free of loosened foreign material, and painted while still at an elevated temperature. (I. 31.)

Flame Scarfing. A method of removing the surface defects from blooms or slabs by means of a bank of torches. (See LIN-DE-SURFACER.)

Flame Sealing. A process in the galvanizing of wire in which the wire, immediately after passing through the molten zinc bath, is passed through a carefully controlled flame with the object of obtaining a uniform coating.

Flame Softening. The operation of passing a torch over a flame cut edge so that the rate of cooling can be controlled and the strains resulting from rapid cooling can be eliminated. (T. 12.)

Flame Spinning. A method of forming steel and other metals in which the material is rotated in a suitable spindle or chuck and while rotating is brought up to forging temperature and formed to the desired contour by a specially designed tool. It is claimed that relatively heavy sections can be so formed. (H. 19.)

Flame Strand Annealing. A method of heat treating wire by passing it through a series of accurately controlled gas flame jets.

Flame Test. A method of detecting the presence of a chemical element in a substance by the colouration given when heated in the flame of a *Bunsen burner*.

Flame Washing. The flame cleaning of castings.

Flange. (*a*) A projecting rim, e.g. at the ends of tubes for connecting them together, or on a wheel which runs on rails, or at the top and bottom of a structural I beam, or on a cylinder, for bolting on the cover. (*b*) A stiffening member or the means of attachment to another member.

Flange Quality. Steel plates intended for application in pressure vessels, not exposed to fire or radiant heat. Special manufacturing, testing and marking is required on this product.

Flanging Test. A test of the ductility of tubes, in which the tube is turned over to form a *flange* at right angles to its axis, until the diameter of the flange measures a specified percentage in

excess of the original diameter of the tube.

Flank. In a twist drill that surface on the point which extends behind the lip to the following *flute*.

Flaring Test. (See EXPANDING TEST.)

Flash. (*Fash, Fin, Shift, Twist.*) (*a*) The metal that is in excess of that required to fill the final impression in a pair of *forging dies* and is exuded as a thin plate at the parting line between the dies. (*b*) A thin fin of metal formed at the mould joint or parting in a casting due to the *cope* and *drag* not matching properly. (*c*) In spot welding, an extruded fin of metal concentric with the spot and situated between two spot-welded plates. (*d*) In pressure welding, the metal squeezed out of a joint made by the resistance-welding process. (*e*) (See BURR).

Flash Attack. A phenomenon sometimes observed on immersing certain types of free-machining steels in nitric acid when a reaction occurs around the sulphide inclusions.

Flash Baking. A method of treating wire or strip in which the coils are dried in a gas-heated oven for 10 to 20 minutes in order that the rusting process may be completely arrested and any hydrogen, occluded as a result of the pickling treatment, eliminated. (H. 65.)

Flash Butt Welding. A resistance butt welding process wherein the necessary heat is derived from an arc or series of arcs established between the parts being welded prior to the application of the weld-consummating pressure, which is applied when the heat thus obtained has produced proper welding conditions.

Flash Line. The line appearing on the profile of a forging after the removal of the *flash*.

Flash Melting. (See FLOW BRIGHTENING.)

Flash Pan. The part of a die which has been machined out in order to allow the excess metal to escape.

Flash Point. The temperature at which an oil, heated in a *Cleveland cup* (open test) or in a *Pensky-Martens* apparatus (closed test) gives off sufficient vapour to flash momentarily on the application of a small flame. The test is particularly applicable to quenching oils. This is an indication of the fire risk involved in handling the oil.

Flash Welding. A resistance welding process applied to rod, pipe, and sheet to produce a butt joint. After the current is turned on, the two parts are brought together at a predetermined rate so that discontinuous arcing occurs between the two parts to be joined. This arcing produces violent expulsion of small particles of metal (*flashing*) and produces a positive pressure in the weld area which excludes air and minimizes oxidation. When sufficient heat has been developed by flashing, the parts are brought together under heavy pressure so that all fused and oxidized material is extruded from the weld. (W. 61.)

Flashback. A recession of the flame into or back of the mixing chamber of the welding torch.

Flashing. (*a*) Specially prepared sheet steel or other material used principally at the edges of roofs and around chimneys and vents to make the roof water-tight (U.S.A.). (*b*) (See FLASH WELDING).

Flashing Time. In *flash welding* the time during which the flashing action is taking place.

Flask. (*a*) (*Moulding Box*). A frame made of iron or wood which holds the sand round the *pattern* during the preparation of the *mould*. A flask consists of two or more boxes. The lower box is called the *drag* or *nowel* and the upper box the *cope*. If the flask consists of three parts, the intermediate portion, between the drag and the cope, is known as the *cheek*. A *false cheek* occupies the same position as a cheek and performs the same functions but is contained within the cope and drag. *Guide* or *box pins* are secured to lugs in the drag and pass through holes in corresponding lugs in the cope so that the parts can be replaced in their exact relative positions. In *snap flasks* both drag and cope are hinged at one corner and are provided with latches at the opposite corner so that when the mould is completed the flask can be unfastened and lifted away. (*b*) An iron bottle for holding 76½ lb. of mercury. (*c*) Glass vessels, varying in size and shape, used in chemical analysis.

Flask Pins. *Guide* or *box pins* used to assure proper alignment of the *cope* and *drag* of the *mould* after the pattern is withdrawn. (See FLASK.)

Flat. A bar of rectangular section in which the width is greater than the thickness.

Flat Back. A *pattern* with a flat surface at the joint of the *mould*. Thus, a flat back pattern lies wholly within the *drag* and the joint of the *cope* is a plane surface. (P. 1.)

Flat Die Forging. (See SMITH FORGING.)

Flat Die Rolling. (See THREAD ROLLING.)

Flat Downhand. Synonymous with *downhand weld*.

Flat Gate. A wide *gate* with a narrow opening into the *mould*. It is used for pouring thin flat *castings*. (P. 1.)

Flat Position. The position of welding wherein welding is performed from the upper side of the joint, and the face of the weld is approximately horizontal. (A. 37.)

Flat Rammer. (See RAMMER.)

Flat Sheet. Sheet rolled as pieces of convenient size and then flattened or levelled, usually by stretching. This operation may produce properties slightly different from those of coiled sheet.

Flattened Wire. Wire with rounded edges and constant width but which has been flattened by rolling.

Flattening. (See ROLLER LEVELLING.)

Flattening Test. (*a*) A test applied to steel tubes in which a section, one or two inches in length, is cut from a tube and bent into an oval section by pressure so that its diameter is reduced when under load to 0·85 times the original diameter, without cracking. (*b*) A test for rivets in which the head is flattened, while hot, until its diameter is $2\frac{1}{2}$ times the diameter of the shank.

Flatter. (*a*) A steel tool used in hand forging to produce a flat surface. (*b*) A *draw plate* used in the production of wire.

Flatting. (See KINKING.)

Flavite. A name proposed for iron nitride which, on etching with picric acid, appears in the microstructure of steel as a yellow constituent.

Flecks. Surface defects arising, for example, in polished sheet, caused by the presence of silicate inclusions.

Flex-Tester. An instrument used to bend a corner of sheet material through a given arc. The resistance of the material to the bending force causes a tongue portion, acting as a cantilever spring, to deflect. Such deflection is recorded on a dial gauge in *F units*, and comparative *F values* are obtained by making a simple correction for sheet thickness, the commonly used 0·035 in. thickness being taken as standard. A special spherometer is used to measure the maximum curvature of the flexed corner; the highest dial unit obtained is the deflection of the material in 0·001 in. across the span of the two outside instrument points. Dial units are termed *R values*. (B. 125.)

Fleximeter. An instrument developed to permit the determination of the state of stress due to bending moments (*flexures*) alone at any given point on a structure. When used in conjunction with an equilateral *strain gauge rosette*, the fleximeter permits the determination of the axial stresses and the stresses on the inaccessible side of the sheet from external measurements alone. (B. 92.)

Flexural Strength. The resistance of material to bending.

Flexural Stress. The stress set up in a body on bending, e.g. on bending a body which was originally straight, compressive stresses are set up on the inner side of the angle and tensile stress on the outer.

Flexure. The capacity of a body to bend without fracture.

Flexure Test. Specimens of specified length in the form of sheet, strip, rod or wire, clamped at one end, are bent by applying a load at the free end. The load and angle of bend are indicated on a visual scale. (See also TOUR MARSHALL TEST.) (E. 21.)

Flintkote. An emulsion of petroleum asphalt in water for the protection of steel against the action of seawater.

Float Cut. (See CUT.)

Floating Plug. (*Plug Die.*) A plug positioned inside a tube during drawing, in such a way that the tube is reduced in thickness between the plug and the die.

Flocast. A patented process for the continuous casting of iron bar. The metal is melted in a cupola and is transferred thence to an oil-fired holding furnace which contains a Salamander crucible. Molten metal is maintained in this crucible continuously, and in the bottom there is a special die with an aperture of the required size. A jacket, through which water circulates continuously, surrounds the die, and the solidification rate of the metal is controlled by automatic adjustment of the rate of water flow. When starting casting, a steel bar of appropriate diameter, threaded at the end, is inserted at the base of the die, and, on filling the crucible, the molten iron freezes to the steel bar and drawing commences. At regular intervals thereafter, determined by experience, the bar is drawn downwards for a certain distance, so that the length which has solidified in the die is pulled out. (M. 50b.)

Flodin Process. A direct process for the manufacture of steel, by means of which iron with a carbon content from 0·2% upwards can be produced by smelting, in a specially constructed electric furnace, a mixture of haematite and coal, or charcoal, the process being continuous. The reduced metal accumulates at the bottom of the furnace from which it is tapped. Both sulphur and phosphorus are reduced to a low figure without additional refining, whilst the manganese and silicon contents are controlled in the same way as in the ordinary open-hearth process. It is

the other hand, no permanent record is obtained, more power is required to produce visible images than to produce X-ray negatives, and the human element enters largely into the interpretation, which must be done immediately. (C. 38.)

Fluoroscopy. (See FLUOROSCOPIC INSPECTION.)

Fluorspar. *Calcium fluoride* ore, corresponding to the formula CaF_2. It occurs in abundance in the United Kingdom. It is chiefly obtained from the counties of Durham and Derbyshire, and is often found in association with lead and zinc minerals. Fluorspar is added to the metal bath in steelmaking to promote slag fluidity and, in the basic process, to assist in the removal of sulphur and phosphorus. (O. 18.)

Flush. A term applied to a *butt weld* where the weld face is in the same plane as the surface of the parts joined.

Flushing. (*a*) A term applied in U.S.A. open-hearth practice to a method of slag removal. The method is based on the use of a high percentage of molten pig iron which results in a copious evolution of carbon monoxide gas. This in turn causes foaming of the slag which is allowed to stream out of the furnace through openings provided for that purpose. (*b*) The removal of cinder from a *blast furnace*.

Flute Run-Out. That section of a twist drill, situated at the shank end of the flutes and formed by the drill fluting cutter as it leaves the drill body at the termination of its cut.

Flutes. The grooves in the body of a twist drill which provide lips and permit the removal of chips and allow cutting fluid to reach the lips.

Fluting. Kinking or breaking caused by the curving of metal strip on a radius so small, in relation to thickness, as to stretch the outer surface well beyond its *elastic* limit. Fluting may also occur in cold worked sheet or strip when the metal fails to bend uniformly through a uniform arc, although the radius is not small, kinking only in certain defective areas.

Flux. (*a*) Material used to dissolve or exclude the formation of oxides from the surface of the metal during *welding*, *brazing* or *soldering*, and/or to add ingredients to improve the properties of the weld metal. (*b*) Limestone used in the *blast furnace* to combine with the earthy or other impurities of the ore, so as to produce a fusible slag and thus facilitate the separation of impurities from the reduced metal. (*c*) *Lime*, *limestone* or *fluorspar* used in the manufacture of steel, for the production of a fusible *slag* and to adjust its fluidity. (*d*) Material which lowers the melting point of a refractory material.

Flux-Coated Electrode. A rod of filler metal on which a coating of flux has been baked for use in *arc welding*. (A. 27.)

Flux Density. (See MAGNETIC FLUX DENSITY.)

Flux Dip Brazing. A term used for the salt bath brazing of special work when use is made of salts which have a particularly powerful fluxing action. The flux dip method is usually applied in the brazing of metals such as aluminium and high chromium steel which have exceptionally stable oxides. (W. 21.)

Flux Injection Cutting. (*Flux Oxygen Cutting.*) An oxygen-cutting process wherein severing of metals is effected by using a flux to facilitate the cutting. This process uses a finely divided non-metallic flux of comparatively simple composition, which is carried directly in the cutting oxygen stream. With this method, the flux and cutting oxygen reach the face of the cut simultaneously and the refractory oxides are fluxed as fast as they form. The process uses, with minor adaptations, standard cutting equipment. (B. 36.)

Flux Oxygen Cutting. (See FLUX INJECTION CUTTING.)

Flux Process. A method for the production of tin or terne plate in which the surface of the bath of molten tin or lead-tin alloy respectively is covered with a flux consisting of zinc chloride with or without the addition of ammonium chloride.

Fluxing Ore. An ore which contains sufficient fluxing agents, together with its metal content, to be self fluxing.

Fly Ash. A finely divided product of combustion.

Fly Ash Erosion. The erosion of metals by the impingement of particles of ash suspended in rapidly moving gas streams. (F. 17.)

Flying Mike Continuous Gauge. (*Electrolimit Gauge.*) An instrument used in cold rolling mills to control, within close limits, the thickness of strip metal. The gauging points are in continuous contact with the surface of the travelling strip, and error in thickness is instantly detected, magnified and registered by an electric circuit with a needle moving on the meter dial. (M. 124.)

Flying Shear. A shear, usually steam operated, which severs steel as the piece continues to move. In continuous mills, the piece being rolled cannot be stopped for the shearing operation, so the shear knives must move with it until it is severed.

Flying-Spot Microscope. An instrument in which a cathode-ray tube is placed before the microscope eyepiece, thus providing a televising raster of high brilliance and a very short time-constant, so that the objective produces a minute spot of light which scans the specimen. The transmitted light falls on a multiplier photocell, the output from which modulates the raster on a second cathode-ray tube, of projection type. A trial apparatus of this type has shown many advantages compared with orthodox microscopy, including those inherent in television, and the possibility of quantitative analysis. (Y. 6.)

F.O.B. *Free on board.*

Focke-Wulf Hardness Tester. A portable hardness testing instrument which uses the Rockwell principle of pre- and main-loading. Brinell and Vickers hardnesses can also be determined. The instrument weighs about 2 lb. (T. 7.)

Focometer. An instrument for measuring the focal length of a lens.

Focus. In X-ray tubes, the spot on the target where the cathode-rays are concentrated and which is, therefore, the principal source of X-rays; its shape and size are controllable by design. (A. 27.)

Focusing. In methods of X-ray or crystal analysis, using such a shape and position of sample and position of source that the diffracted X-rays from many or all parts of the sample fall close together in the diffraction pattern. Such methods permit the use of wide beams and require relatively short exposures. (See BRAGG METHOD and SEEMANN-BOHLIN METHOD.) (A. 27.)

Foeppl Hardness Test. A method of testing hardness in which two pieces of the material under test are pressed together under constant load.

Foeppl-Pertz Damping Tester. Apparatus for determining the *damping capacity* of a material in which a specimen is held vertically, and caused to vibrate. The damping capacity is determined from the rate of decay of the amplitude of vibration by one of several methods of computation. (C. 51.)

Fofumi Furnace. An oil-fired rotary melting furnace manufactured in Sheffield under the Deblanchal patent. It is claimed to have a very low operating cost and also to possess the advantages of low oxidation due to controlled atmosphere, thus making possible additions of alloys to the melt without stopping rotation, and the removal of samples without stopping the furnace. A recuperator with alloy steel tubes is in the waste-gas flue and this heats the air passing to the burners. The furnace is made in capacities of 1 to 10 tons, and it is claimed that a steel charge of 5 tons can be poured in 2 hours after lighting up. A temperature of 1750° C. can be obtained within 1½ hours if rapid heating is required. (M. 121.)

Fog Quenching. A method of quenching in which a fine vapour or mist is used as the quenching medium. (See also SPRAY QUENCHING.) (A. 27.)

Fogging. A term applied to the oxidation of nickel and certain high nickel alloys on exposure to humid air containing a relatively high contamination of sulphur dioxide, such as may occur in an industrial atmosphere.

Foil. Metal in any width but no more than about 0·005 in. thick. (A. 27.)

Foil Strain Gauge. An electrical resistance strain gauge made from thin foil, using a strain-sensitive resistance foil printed into a thin lacquer film. (E. 33.)

Folding Test. A forging test which requires that the metal or steel in question should be bent, either hot or cold, according to specification, through an angle of 180° without cracking, the force being slowly applied.

Folds. Defects caused in metal by continued fabrication of overlapping surfaces. (A. 27.)

Folgerite. A name given to a mineral consisting of sulphide of iron and nickel, subsequently found to be *pentlandite.*

Follow Board. A board which conforms to the form of the pattern and defines the parting surface of the *drag.* (A. 26.)

Follsain Penetral Process. A method of *chromizing* in which iron or steel articles are packed in a mixture of powdered aluminium, chromium oxide and carborundum, which acts as a diluent, and subjected to a temperature of 850° to 1000° C. for 3 hours or more. An aluminothermic reaction takes place, producing a cemented layer of high chromium content on the articles under treatment. (F. 32.)

Follsain Process. A method for the sintering of the raw materials for the burden of blast furnaces in which continuous sintering (*nodulizing*) is carried out in a rotating tube furnace; at the discharge end is arranged a special *tuyere* comprising two concentric close-ended tubes parallel to the furnace axis, the outer tube having one nozzle near its closed extremity, the other having a number of nozzles protruding through the outer tube. The inner tube supplies air heated to 650° to 800° C.; the outer one carries cold air, which keeps the inner tube from softening and becoming deformed and itself becomes somewhat

heated by the time it emerges from the nozzle. These jets are directed upon the material to be sintered. The fine iron-bearing material is mixed with a proportion of fuel; under the intensive action of the hot air blast, the fuel raises the temperature of the mixture sufficiently for sintering to occur, whereupon the material is discharged from the furnace. (S. 2.)

Fool's Gold. (See PYRITES.)

Foolscap. A size of paper $13\frac{1}{2} \times 17$ in. (printing), $13\frac{1}{4} \times 16\frac{1}{2}$ in. (writing). It is so called from the 17th-century watermark of a dunce's cap. (See also BOOK SIZES.)

Foot-Pound. The English unit of *work* which represents the energy required to lift a pound weight through a distance of one foot. Similarly a pound weight falling through a distance of one foot will perform one foot-pound of work.

Footner Process. A process for the descaling, phosphating and priming of steel, which follows the cycle of operations: (i) immersion in 5% H_2SO_4 at 65° for 15 to 25 minutes; (ii) after draining, two dips in water at 60° to 65°; (iii) immersion for 3 to 5 minutes in a solution containing 2% of free H_3PO_4 and 0·3% to 0·5% of iron at 85°; and (iv) priming while still warm. The immersion in phosphoric acid produces an adherent coat of rust-inhibiting iron phosphate, which is an excellent key for paint.

Force Between Two Charges. (See COULOMB'S LAW.)

Fordath Process. (See "D" SHELL MOULDING.)

Forehand Ripple Welding. A technique in gas welding in which the flame impinges at a point between the tip of the welding rod and the completed portion of the weld.

Forehand Welding. A gas-welding technique wherein the flame is directed towards the progress of welding (A. 37.)

Forehearth. A brick-lined reservoir in front of the cupola. (A. 26.)

Foren Process. A method of rolling seamless tubes in which a solid round billet is cast and pierced by a rotary piercer to give the required inside diameter and wall thickness. It then goes to the Foren mill. A solid mandrel of alloy steel is inserted into the billet, and the latter is operated on by pairs of rolls, disposed along the length of the billet and set at various angles, so as to exert a kneading action on the whole circumference of the billet. Stripping rolls remove the tube from the mandrel, and the process is repeated. It is claimed that six tubes, 40 ft. long, may be produced per minute; the tubes are said to possess a good surface and grain structure. (E. 86.)

Foreplate. A plate situated in front of the lower roll in a *rolling mill* to assist in guiding the steel into the correct position between the rolls.

Forge. (*a*) The term as used as a verb (see FORGING (*a*)). (*b*) A workshop or plant where iron or steel are forged at red heat. Such plants may vary from a blacksmith's forge consisting of a hearth with a forced draught for heating the steel which is later worked on an anvil with a hammer, to the steel works plant where forgings of 60 tons or more are worked under a 6000-tons press. (See FORGING.) (See Plate XII.)

Forge Delay Time. In spot and projection welding, the time between the beginning of weld time, or weld interval, and the time when the *electrode* force first reaches the specified pressure for forging. (A. 37.)

Forge Pigs. Pig iron suitable for the production of wrought iron by the *puddling* process.

Forge Scale. Iron oxide produced on the surface of the product during forging.

Forge Welding. (*Hot Pressure-, Recrystallization-, Solid Phase-, Hammer-* or *Smith Welding*.) A welding process in which union is effected by heating in a blacksmith's forge or other furnace and by applying pressure by means of hammering.

Forgeability Test. (See UPSETTING.)

Forgemaster. (*a*) A manufacturer of forgings. (*b*) An installation comprising a *radiation pyrometer* together with accessory automatic recorders and electronic control for recording and controlling the temperatures of forging furnaces.

Forging. (*a*) Working metal parts to a finished shape by means of hammering or pressing after the material has been rendered plastic by heating to a high temperature. Forging may be carried out by *hammer forging* (See Plate III), *press forging* (See Plate XII) and *drop forging* or *stamping*. Hammer forging is carried out by hand, steam or pneumatic hammers and deformation is brought about by a number of sharp successive blows of short duration, i.e. by shock. Press forging is done by hydraulic presses, and the deforming pressure is applied for longer intervals, giving opportunity for plastic flow to take place. (*b*) The product of the forging operation. (See also DROP FORGING.)

Forging Burst. A defect consisting of a mechanically generated *pipe* or void, induced during forging.

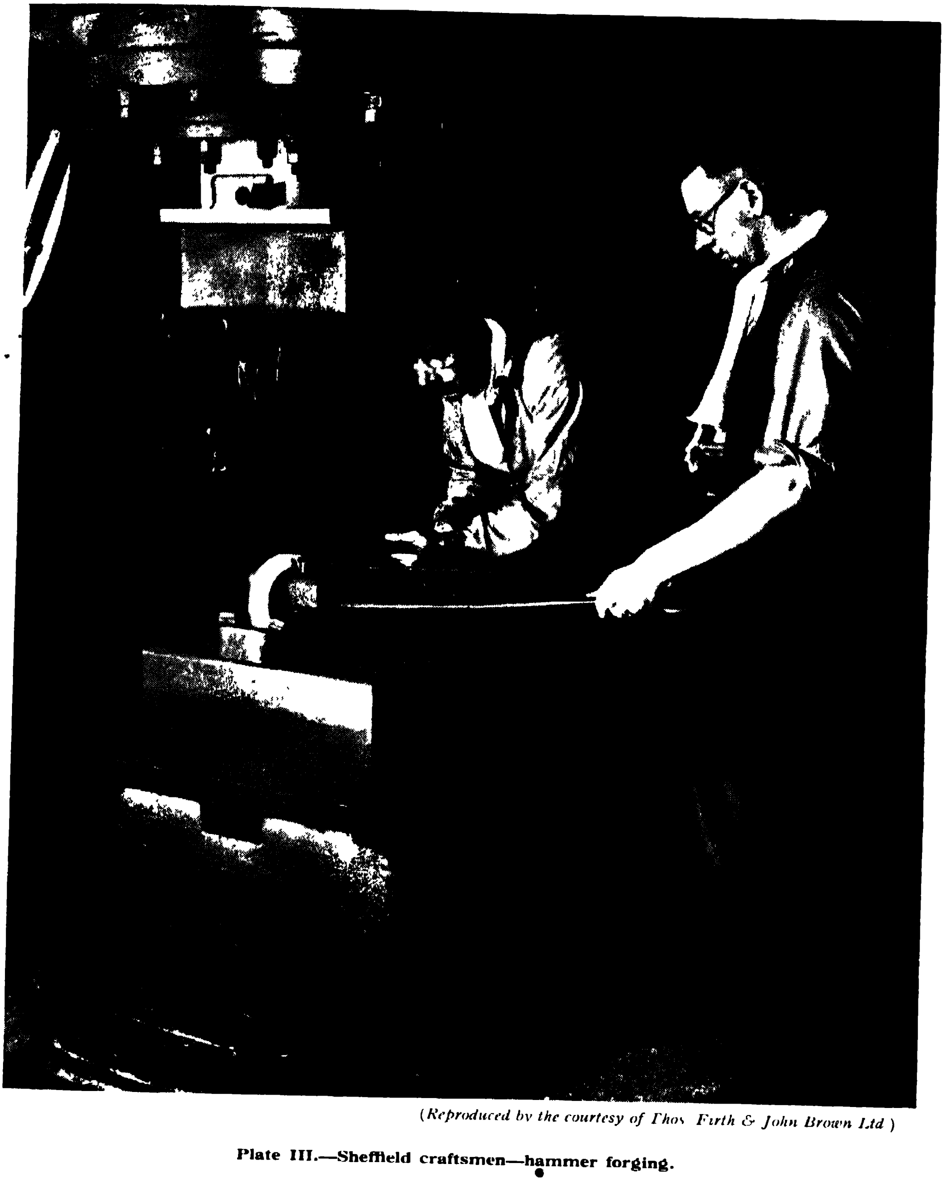

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Plate III.—Sheffield craftsmen—hammer forging.

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Forging Cross. A phenomenon consisting of a clearly visible cross-shaped design which appears on the etched surfaces of specimens which have been rotated during forging, between blows of the hammer, to positions at right angles to one another.

Forging Ingot. An ingot intended for forging.

Forging Machine. (See MACHINE-FORGING.)

Forging or Upsetting Tests. Tests in which short pieces cut from *billets* or *bars* are forged or *upset* either hot or cold and the condition of the piece is examined. Defects such as *seams* or excessive non-metallic *inclusions* will cause the surface to burst as the metal is expanded.

Forging Quality. Steel which has been processed to remove defects that may be revealed in a *bar* or *billet* by subsequent forging.

Forging Rolls. *Rolling mills* that forge comparatively uniform shapes by using variable radii around the circumference of rolls that rotate in the opposite direction from those ordinarily used for rolling. (A. 27.)

Forging Round. A stage in the operation of forging an ingot into the finished forging.

Forging Strains. Strains that have been set up in the metal during forging or during cooling after forging. They are usually relieved by subsequent *heat treatment* consisting of annealing or normalizing.

Forging Temperature Range. The maximum and minimum temperatures within which hot working operations should be carried out. If the upper temperature limit be exceeded detrimental overheating may occur, whilst if work be continued after the steel has cooled to below the lower limit, cracking may result.

Forging Thermit. (See THERMIT.)

Fork. A tool, shaped like a two-pronged fork, used in rolling mills for hand turning up of steel bars and sections in order that the mill-hand can guide the piece into the correct pass in the roll.

Form. (For equivalent crystal planes or lines.) Having the same indices except for sign or order; for example, the planes (110), (101), in a cubic crystal are both of the form (110); the planes (110), (101), in a tetragonal crystal, are not of the same form.

Form Factor. The ratio of the effective value of a symmetrically alternating quantity to its half-period average value. (A. 28.)

Form Strength. The strength of variously shaped members of a complex structure, as compared with that of a standard bar of the same material. (T. 24.)

Formall Process. A process in which a drop hammer is used to produce deep draws in sheet metal, thus effecting considerable economy as compared with the use of hydraulic pressure. The hammer is modified by fitting an upper (falling) forming unit, consisting essentially of rubber pressure pads, and a lower hydraulic die retainer unit with a shock absorber. (D. 27a.)

Former. (*a*) In a closed pass type of rolling, the former is the portion of one roll which indents into the cross-section of the other. (*b*) The *mandrel* round which a material is bent when carrying out a *bend test*.

Former Bend Test. A test in which the specimen is bent round a *former* of specified diameter. The diameter of former, dimensions of specimen, and method of applying the bending force, are important factors which have a decided bearing on the results obtained, and for comparative results these factors should be identical for each test.

Forming. (*a*) A process whereby the planes of a definite shape are changed without materially changing the cross-section. (*b*) In tube making, the process of shaping strip into tubular form by passing through shaped rolls.

Forster Surface Measuring Instrument. An optical instrument, which employs a feeler pin, moved vertically by an impulsing device in a series of quick jumps from one test position to the next. The pin is a sapphire needle of 2 to 10 microns point radius, and can make from 50 to 100 contacts per second. The instrument is fitted with a motor-driven 35-mm. film camera for recording. The magnification is about 2000 times. It is generally used for calibration and research work. (M. 136.)

Forsterite. (*White Olivine.*) A pure *olivine* consisting of magnesium orthosilicate, Mg_2SiO_4, and having a hardness of between 6 and 7 on Mohs' scale. It is a refractory material with a melting point of 1890° C. Its thermal conductivity is about 40% of that of magnesite. The porosity of the mineral varies between 12% and 70%. Among other properties may be mentioned good refractoriness-under-load. It is claimed that Forsterite has been used in Germany with satisfactory results, for the basic linings of induction furnaces. (I. 59.)

Forward Creep. (*Forward Slip.*) As used in the rolling mill the term refers to the tendency of a piece being rolled to increase slightly on the delivery side of the pass so that its speed on delivery

slightly exceeds the peripheral speed of the rolls.

Forward Slip. (See FORWARD CREEP.)

Forward Welding. (*Leftward Welding.*) The technique in which the blowpipe flame is directed towards the open or incompleted joint. (B. 105.)

Foscoat. A zinc-iron phosphate coating for iron and steel. It improves cold forming and facilitates drawing operations. It is applied by immersion or spraying, in which is absorbed an organic lubricant—*Foslube*. (M. 85.)

Foslube. (See FOSCOAT.)

Fossil Flour. (See INFUSORIAL EARTH.)

Foster Fixed Focus Radiation Pyrometer. An instrument in which the heat radiated from a hot body is focused on to a thermocouple by means of a concave mirror. The pyrometer is pointed at the hot body and when equilibrium is obtained the temperature is read from the indicator. The instrument, once focused, gives continuous readings and may be connected to a recording indicator.

Founding. The art of melting and casting of metals.

Foundry. A plant devoted to the production of *castings*.

Foundry Facing. Material, usually carbonaceous, applied to the surface of a sand mould to prevent the molten metal from penetrating and reacting with the sand. (A. 26.)

Foundry Returns. Metal in the form of gates, sprues, runners, risers, and scrapped castings returned to the furnace for remelting. (A. 26.)

Foundry Sands. (See MOULDING SANDS.)

Fountain. An alternative name for the *trumpet* used in *uphill casting*.

Four High Mill. (See ROLLING MILL.)

Fox Inclusion Count Method. In this method samples are taken from the top, middle and bottom of the ingot; each sample is forged or rolled into a bar, which is cut through the axis and the sawn face is prepared for micro-examination. By adopting a magnification of 130 diam., a complete traverse of the section involves approximately thirty fields. The examination of two different lines results in the inspection of sixty fields for each specimen. In order to correlate the results, micrographs were prepared, representative of the range of inclusion groups found in steel of various types, and graded 1 to 4 in increasing order of severity of non-metallic matter content. Of the sixty fields examined, the number of fields corresponding with each grade is multiplied by the grade number, and the sum of the products of all the fields is adopted as the inclusion number for the steel examined. (B. 66a.)

Fraction. (*Cut.*) That portion of a powder sample which lies between two stated particle sizes or two stated screen-mesh sizes. (A. 27.)

Fractional Crystallization. The separation of a mixture of dissolved substances by means of their different solubilities.

Fractional Distillation. The separation of liquids, having different boiling points, by distillation at different temperatures, with the aid of a *fractionating column*.

Fractionating Column. An apparatus inserted between a still and a condenser in the process of distillation. Its purpose is to condense the less volatile portions of the vapour and return them to the still.

Fractograph. A photomicrograph taken at high magnification of the nascent cleavage surface of a solid. An individual facet is first selected for examination by the aid of a magnifying glass. The specimen is then mounted between clamps at right angles to the axis of a microscope by means of a simple orienting mechanism. Neither polishing nor etching is performed, the actual plane of weakness being the only surface examined. The fractograph is particularly important in revealing the pattern of the separation at time of fracture, and also often the physical and chemical factors underlying that pattern, and hence the fracture itself. (Z. 5.)

Fracture. The type of surface found on breaking a piece of steel. A nomenclature has been adopted to describe certain types, e.g. *crystalline* is bright and glittering, failure having developed along the *cleavage planes* of the individual crystals. Such a fracture is typical for a brittle material, e.g. cast iron, which has broken without deformation. In *fibrous* or *woody fracture*, the appearance is due to the elongation of the individual grains and this may be accentuated by the presence of *slag* or by a *banded structure*. It is grey and dull and is characteristic of a ductile but non-homogeneous material such as wrought iron A *silky fracture* has a very smooth fine dull grain and usually occurs in a highly ductile material such as mild steel. In a *granular fracture* the cleavage tends to follow the inter-crystalline boundaries. A *vitreous fracture* characterizes a fine grained non-ductile material. A *tough fracture* refers to a ductile material where failure occurs only after considerable deformation, whilst in a *brittle fracture*, metal fails by cleavage because its

cohesion is exceeded. *Conchoidal fracture* is the shell-like fracture shown by amorphous solids such as glass or pitch which break into irregular pieces having curved surfaces.

Fracture Stress. The maximum principal true stress (fracture load divided by fracture area). (See COHESIVE STRENGTH.) (A. 27.)

Fracture Test. (*a*) A test for carbon in which a *spoon sample* is taken from the molten bath of steel, quenched in water and broken with a sledge hammer, the carbon content being judged by the appearance of the fracture. (*b*) A workshop test which consists of taking a short length of bar, or other test piece, sawing it nearly half-way through, fixing it in a vice with the notch level with the top of the jaws and breaking the pieces with a hammer. The test is carried out after hardening the sample. Considerable information can be obtained from an examination of the fracture and from the degree of bend before fracture occurs. (*c*) A method of determining the *austenitic grain size* in steel which consists in heating a previously notched specimen to a suitable temperature for an appropriate period and quenching drastically in water or brine. The specimen is then broken at the notch and the fracture of the martensitic zone compared with one in a series of standard grain size fractures, e.g. *Shepherd* and *Jernkontoret Standards*.

Fragmentation. Imperfection of the crystal structure of grains in a metal as the result of working. The fragments differ slightly from one another in orientation, and tend to rotate to a stable orientation. (A. 27.)

Franchi-Gregorini Process. A method for the centrifugal manufacture of cast iron pipes. The process employs casting machines which are set up in pairs, each being capable of producing a wide range of diameters and lengths of pipe, and consisting essentially of a long bottom frame designed to carry a special truck mechanically driven. A trough internally lined with refractory forms hangs over the end of this truck. The trough moves horizontally inside the rotating metal mould and pours into it the molten metal in the exact quantity delivered by the pouring ladle. This ladle is made of such a shape that the quantity of metal delivered in the trough during each unit of time remains constant. The quantity of metal poured can be proportioned quickly and easily to the various diameters and thicknesses of the pipes. (F. 42.)

Francis Electrolytic Thickness Tester. A thickness tester for plated metal coatings which operates by the anodic dissolution of a defined area of the plated metal and uses the product of current and time as a measure of thickness. The stripping current is held constant and the removal time automatically indicated. It is necessary that the coating be anodic to the base metal in the electrolyte employed and that it dissolves at 100% current efficiency. Constant stripping voltage is maintained by a 90V battery which, when stripping is complete and the stripping-cell voltage consequently rises, operates an electronic relay, opening the circuit, and stopping a clock. (F. 43.)

Frankland, Sir Edward. (1825–99.) An English chemist and the originator of the concept of valency.

Franklin, Benjamin. (1706–90.) An American physicist.

Franklinite. An iron ore (Fe_2O_3ZnO) which is worked only in New Jersey, U.S.A.

Frasing. (See DEFRASING.)

Freckles. Dull spots on the surface of tinned plate.

Free. A term applied to elements which exist as such and are uncombined with any other.

Free Bend Test. A test for welded joints, originally devised in America, and specified in the Power Boiler Construction code of the American Society of Mechanical Engineers. The specimen, of width 1½ times the thickness, is given an initial bend at each end and is then placed like a strut in a compression machine. Pressure is applied gradually until failure occurs in the outer fibres of the specimen. (P. 16.)

Free Carbon. Uncombined carbon, i.e. *graphite*.

Free Cementite. The *cementite*, seen in *hypereutectoid steels* and *white cast iron*, which is not associated with *ferrite* to form *pearlite*.

Free Cone Bend Test. A ductility test designed to determine the limiting radius of bend in a single operation. The apparatus consists of an upper and lower steel platen; attached to the lower platen are two rectangular guide members on which the upper platen is free to slide vertically. The platens are tapered and so disposed that the perpendicular distance between their inner faces increases progressively from one end to the other. There is a small semicircular groove running longitudinally through the centre of each of the inner faces, and four adjustable screw stops are provided to arrest the downward movement of the upper platen in any desired position. Pressure

is applied to the upper platen through a shank attached to its upper face, and the distance through which it has moved may be measured at any stage of the test by reference to a scale attached to one of the guide members. The test piece, which is in the form of a trapezium, is mounted between the platens with its converging edges resting in the semicircular grooves. Pressure is applied to the upper platen. When the radius of bend at the narrow end of the test piece becomes too small for the material to withstand, a crack develops and extends along the test piece to the point where the radius is just sufficiently large to allow satisfactory bending. The radius at this point is the limiting radius of free bending and may be measured by means of radius gauges. (T. 21.)

Free Crystals. (See EQUIAXED CRYSTALS.)

Free Cutting Steels. (*Free Machining.*) Steels to which special additions have been made to promote *machinability*. *Sulphur*, *lead*, *selenium* or *bismuth* are elements usually added for this purpose.

Free Ferrite. The *ferrite*, seen in iron and *hypoeutectoid steels*, which is not associated with *cementite* to form *pearlite*.

Free Machining. (See FREE CUTTING STEELS.)

Free on Board. (*F.O.B.*) A price so quoted indicates that the seller is responsible for the loading of the goods on to the ship and all expenses incurred therein. (Cf. *F.A.S.*)

Free Overside. A term indicating that the buyer is responsible for goods as soon as they are unloaded from the ship.

Freeman Wear Testing Machine. A machine for the investigation of the resistance of hard metals to sliding friction. It comprises a 2-in. steel shaft resting on four wide-flanged discs, two at either end, which act as roller bearings for the rotating shaft. Near mid-length of this shaft are keyed two wearing rings of some desired metal or alloy to be studied. These are $\frac{1}{8}$ in. wide and $2\frac{7}{16}$ in. outside diam., and are held by locking rings. The weighed specimens, consisting of small blocks, ride on these rings. The surface of contact on the specimen is ground to the same radius as the ring on which it wears. Two specimens are mounted in a special holder which in turn is bolted to the cast iron housing. This housing straddles the shaft, and the entire load is carried by the curved surfaces of the two test blocks, through the rings on the rotating shaft, to the machine frame. Unit load between rubbing surfaces is then adjusted by counterweights and a lever system attached to the housing. (F. 46.)

Freezing Point. The temperature at which a fluid solidifies, which is the same as that at which the solid melts (the *melting point*).

Frémont Etching Reagent. An etchant consisting of 10 g. of iodine and 20 g. of potassium iodide in 100 ml. of water.

Frémont Test. A notched type of impact test in which a test piece, 8 mm. × 10 mm. section and 30 mm. long, is supported horizontally on supports 21 mm. span. The notch is 1 mm. deep and 1 mm. wide and of a square shape made on the broadside at the centre of length. The piece is fixed with the notch on the underside, and receives a blow from the *tup* which has fallen through a height of several metres. The difference between the initial and residual energy of the tup is the amount absorbed in fracturing the piece. The striking velocity in this test is higher than that in the *Izod* or *Charpy* test.

French Calorie. (See CALORIE.)

French Technical Centre for the Foundry Industry. (See LE CENTRE TECHNIQUE DES INDUSTRIES DE LA FONDERIE.)

Frequency. The number of vibrations, waves, or cycles, of any periodic phenomenon per second, e.g. of electric current, light, or sound waves.

Frequency Factor. (For crystal planes of a *form*.) The number of different families of planes having the same form. (A. 27.)

Frettage. (See FRETTING CORROSION.)

Fretting. Wear that occurs when two materials are rubbed together with a reciprocating motion of limited amplitude.

Fretting Corrosion. (*Chafing Corrosion, False Brinelling, Frettage, Friction Oxidation.*) The mutual corrosion at the contact surfaces of closely fitting machine components that may occur when subjected to vibration. It is a feature of fretting corrosion that the susceptibility of attack appears to increase with the closeness of the fit and the degree of finish, but no deterioration of the surface takes place if the machine is at rest, nor will vibration alone cause corrosion, but it is established that some surface slip, alternating in direction, is the necessary condition. It is probably to be ascribed to conjoint action, i.e. to chemical and mechanical factors operating together. In the presence of air, the film formed on the surfaces, kept hot by friction, may thicken sufficiently to show interference colours,

and may reach a thickness of 2000 Å. Sooner or later, however, the oxide will rub off, forming a fine dust, frequently known as *cocoa*, but sometimes inaccurately described as rust. (T. 37.)

Fretz Moon Process. A continuous *gas-welding* process for the production of welded pipe. As each coil of *skelp* is unreeled it is welded to the end of the preceding reel and the material is passed continuously through a small cross-section heating furnace. The skelp is pulled over water-cooled skids in its passage through the furnace, and on leaving the furnace passes through the pipe forming rolls, receiving a jet of air on the hot edges before passing through the welding machine. The skelp then passes to the sizing machine, and to the hot saw, and on to the cooling beds. After being cooled, the pipe is passed through straightening rolls and is then tested under hydrostatic pressure. All the pipe produced is given one of three finishes, hot galvanizing, black enamelling or electrogalvanizing. (I. 22.)

Friction. The resistance to motion which is called into play when an attempt is made to slide one surface over another. It has been shown that the friction between metals is due to the shearing of junctions formed by adhesion or welding at points of intimate contact. The surface temperature, measured by using the rubbing contact of two different metals as a *thermocouple*, is dependent on the load and speed of sliding, and may reach the melting point of one of the metals. (B. 72.)

Friction Oxidation. (See FRETTING CORROSION.)

Friction Rusting. (See FRETTING CORROSION.)

Friction Sawing. A cutting operation depending upon the fact that momentary contact between the material being cut and the fast-moving blade produces enough friction to heat locally the material to its softening point, thus facilitating its removal by the saw. It is claimed that friction sawing cuts many times faster than conventional methods. Stainless steels, armour plate and hardened tool steel may be cut, but brass, bronze, aluminium and glass are unsuitable for the process. (M. 51.)

Fringe Crystals. Crystals which have formed in a direction at right angles to the surface of a casting.

Fritting. The bonding together of materials by heating until the adjacent surfaces become sufficiently sticky or pasty to cohere. The term is often used in connection with the preparation of furnace linings. In *powder metallurgy*, the term is applied to the sintering of a compact in the absence of a liquid phase.

Front Slagging. An American term for a process wherein both slag and metal flow out through the tap hole. The slag is then skimmed off the surface of the molten metal. (A. 26.)

Front Top Rake. (See RAKE.)

Frozen Stress. A technique which, as generally practised, consists of the fabrication of a model in transparent plastic of the engineering component under study, the subjection of the model to thermal treatment whilst loaded in the same manner as the component is loaded in service, and the subsequent slicing of the model. The slices are viewed in a polariscope and relative retardation measurements taken of the permanent birefringence induced by the process; these measurements allow a quantitative estimate of the stress in the component. The regions of a model of greatest interest to the engineer are the stress concentrations, which nearly always occur on the outer surface at points where one or both of the principal radii of curvature are small. (See also PHOTOELASTICITY.) (H. 55.)

F.R.S. (*a*) Fellow of the Royal Society. (*b*) Fuel Research Station.

Frustum. A charging mechanism, developed for use in a *blast furnace*, which consists of a moving skirt dividing the *hopper* into an inner and outer part. The frustum, which can open or close the outer section of the hopper by being lifted above, or lowered below its mouth, aims to build up consecutive charges in a predetermined manner to give a desired gas flow over the whole area of the stack. (D. 21.)

Fry Lines. Lines appearing internally in mild steel sections subjected to tensile stresses; they are usually associated with heat treatment.

Fryolux. A proprietary mixture of powdered *solder* and *flux*, used for many purposes, including the tinning of bearing shells.

Fry's Etching Reagents.

	No. 1	*No. 2*	*No. 3*	*No. 4*
Cupric chloride	1·5 gr.	4 gr.	5 gr.	90 gr.
Hydrochloric acid	30 ml.	20 ml.	40 ml.	120 ml.
Water	95 ml	40 ml.	30 ml.	100 ml.
Ethyl alcohol	30 ml.	20 ml.	25 ml.	

No. 1 is used for the etching of carbon or alloy steels and No. 2 is specially developed for high alloy steels. Nos. 3 and 4 are both used for showing up the strain lines in cold worked steels, No. 3 being used for microscopic and No. 4 for macroscopic examination.

F.S. Federal Specification.

F Units. (See FLEX-TESTER.)

Fugacity. The tendency of a substance to escape or disappear from the phase in which it is present. The tendency of a gas to escape from an enclosed space.

Fulbond. Proprietary varieties of *Fuller's earth* supplied to foundries for use in green sand mixtures, e.g. Fulbond No. 1 is a natural Fuller's earth dried and ground under controlled conditions, whilst Fulbond No. 2 is modified to obtain greater strength.

Fulcrum. The point of support or pivot of a lever.

Full Annealing. A softening treatment in which the steel is heated to and held for a suitable length of time at a temperature above the *transformation range* and cooled at a predetermined rate. The slower the rate of cooling the lower the hardness will be. The steel is usually allowed to cool slowly in the furnace, but it can be removed and cooled in some medium, e.g. ashes, which ensures a slow rate of cooling.

Full Automatic Weld. (See AUTOMATIC WELDING.)

Full Chamfer. (See CHAMFER.)

Full Coining. (See COINING.)

Full Finishing Backplate. (*Uncoated Tin Plate Base.*) Uncoated material which otherwise has had a full tin-plate mill processing.

Full Strip. Strip in which the edges are shorter than the middle thus causing distortion of the cross-section.

Fuller. The part of the *die* used for reducing the cross-section of the stock, in *die forging*.

Fuller's Earth. A type of clay found in Surrey and Kent, it consists essentially of aluminium-, magnesium-, and ferrous hydrosilicates. It is used as an additional clay for *facing sands* for dry sand moulds. (See FULBOND.)

Fullering. (*a*) Making grooves in forged material by means of a *fullering tool.* (*b*) Tightening the seam of a riveted plate to make it watertight by means of a *caulking tool*.

Fullering Tool. A tool consisting of two parts for producing grooves in forged material. The work is placed between the two parts, the lower part being supported on an anvil, whilst the upper part is struck with a hammer.

Fulmer Research Institute, Ltd. Stoke Poges, Buckinghamshire. The Institute was founded in 1947 to provide research facilities for industrial firms and other organizations. It is equipped to deal primarily with metallurgical problems but work outside this field has been carried out.

Fulmina Furnace. A rotary oil- or gas-fired furnace for the production of high-grade iron and steel castings and malleable castings. It may be used in conjunction with the cupola for refining and alloying the iron produced in the latter. It is produced in sizes ranging from 220 to 33,000 lb. capacity. (E. 65.)

Furnace Block. The initial deoxidation of steel, e.g. by silico manganese, which stops the carbon-oxygen reaction in the furnace. This arrests the carbon drop immediately and makes it possible to secure close control of analysis. If the oxygen content of the metal is reduced well below the level established by the carbon-oxygen reaction, initial deoxidation is accomplished.

Furnace Brazing. A brazing process, in which coalescence is produced by the heat obtained from a furnace, using a nonferrous filler metal having a melting point above 420° C. but below that of the base metals. The filler metal is distributed in the joint by capillary attraction. (N. 23.)

Furnace Cooling. (*F.C.*) Slow cooling of the charge in a heat treatment furnace which is itself cooling down, the source of heat having been cut off. (See ANNEALING.)

Furnace Lining. A lining of a suitable refractory material capable of withstanding attack by the chemical and erosive action of the molten steel. (See ACID- and BASIC-LINING.)

Fusarc Process. An automatic arc-welding process in which the electrode consists of two coiled wires with the flux pressed into them. (K. 41.)

Fuse. (*a*) To melt. (*b*) A device for protecting electrical apparatus from damage by an overcurrent or a short-circuit.

Fuse-Bond Process. A method for preparing the surface of parts to be reclaimed by metal spraying. The principle of the operation is to stroke the surface to be prepared with an *electrode*, which, as it makes contact with the work, passes a high current at low voltage. The cratering of the surface which results, provides a very effective bond for the subsequent spraying operation. By the use of multiple electrodes, large areas such as machine beds or large shafts may be prepared quickly. (P. 35.)

Fusible Alloys. Low-melting point alloys, usually consisting of tin, bismuth and lead, e.g. *Rose's Metal*, melting point 96° C., or tin, bismuth, lead and cadmium, e.g. *Wood's Metal*, melting point 70° C. Ultra low-melting-point alloys can be obtained by the use of the expensive metals, indium and gallium, e.g. a binary alloy containing 8% tin and 92% gallium remains liquid down to a temperature of 20° C. (T. 29.)

Fusion. The change from the solid to the liquid state. Fusion of a substance takes place at a definite temperature, the *melting point*, and is accompanied by the absorption of *latent heat* of fusion.

Fusion Face. A surface to be welded by a *fusion-welding* process.

Fusion Mixture. A mixture of anhydrous sodium and potassium carbonates.

Fusion Point. In refractories, the fusion point is that temperature reached in the heating of a foundry sand or clay at which the specimen no longer holds its shape, due to its softening under heat. (See also MELTING POINT and PYROMETRIC CONE EQUIVALENT.) (A. 26.)

Fusion Thermit. (See THERMIT.)

Fusion Welding. A process of welding where the surfaces to be joined are melted with or without the addition of filler metal, e.g. *Oxyacetylene-*, *Gas-*, *Blowpipe-*, *Electric Arc-*, *Atomic-*, *Hydrogen-*, and *Fusion Thermit-Welding*. The term is generally reserved for those processes in which welding is achieved by fusion alone, without pressure.

Fusion Zone. The portion of a *fusion weld* where the parent metal has been melted, and, if *filler metal* is used, where inter-diffusion has taken place.

Fuze Bond. (See FUSE-BOND PROCESS.)

F Values. (See FLEX-TESTER.)

G

g. (*a*) Abbreviation for *gram*. (*b*) Symbol for acceleration due to gravity.

Ga. Chemical symbol for *gallium*.

Gab. A hook or notch in a rod or lever which enables a temporary connection to be made between the lever and projecting pin for the purpose of imparting motion to the mechanism on which the pin is fixed.

Gad. (*a*) A short steel chisel used for breaking or loosening rock. (*b*) A steel wedge for breaking coal.

Gadd. Sheffield colloquialism for the cutting of steel rod into short lengths.

Gadolinite. A mineral consisting of silica 23·9%, yttrium oxides 51·8%, ferrous oxide 14·3% and beryllium oxide 10·0%.

Gadolinium. (*Gd.*) A very rare metallic element, a member of the rare earth group. *Atomic weight* 156·9. It is trivalent. Hitherto, the metal has not been available for extensive study but natural isotopes of the element are now being separated at the Oak Ridge National Laboratory, U.S.A.

Gag. A rectangular block of steel used in the straightening of rails.

Gag Press. (*Straightening Machine.*) A machine used for *gagging* consisting of a horizontally reciprocating ram midway between two support points on a platen which is so arranged that it can be moved closer to or farther away from the ram, thereby varying the amount of bend made in the shape.

Gagger. An L-shaped steel rod used to support the sand in the *mould* in the production of castings.

Gagging. Straightening bar or tubular products in a *gag press*.

Galaxite, Manganese aluminate ($MnAl_2O_4$).

Galena. (*Lead Glance.*) Lead sulphide (PbS).

Galileo, Galilei. (1564–1643.) An Italian physicist and mathematician.

Galileo Hardness Tester. This equipment enables tests to be carried out on metals with hardness values ranging from 30 to 1000 Brinell. It is provided with various weights whereby six different loads ranging from 31·2 to 187·5 kilograms can be applied to the indenter. A feature of the design is that these weights are housed within the column, and are brought into use, as required, by means of a conveniently placed knob. A hydraulic dashpot system is incorporated providing for gradual application of the load, and when hardened steel balls or a diamond cone indenter are employed, Rockwell hardness readings are obtained by direct reference to magnified images of the scales. Alternatively, a 2·5 mm. diameter ball indenter can be fitted and Brinell hardness obtained from a conversion table, when loads of 62·5 and 187·5 kilograms are applied to the work. A portable microscope having a magnification of 20 × is available, enabling Brinell tests to be carried out using a 5-mm. diameter ball indenter. The instrument can also be used with a pyramid diamond indenter to obtain readings on the Vickers hardness scale, the impression being measured with the aid of a microscope. (M. 43.)

Galling. (*Seizing.*) (*a*) The damaging of one or both metallic surfaces by removal of particles from localized areas during sliding friction., (S. 23.) (*b*) A term used in powder metallurgy for the impairment of the surface of a compact or of die parts caused by adhesion between the die wall and the metal powder.

Gallium. (*Ga.*) *Atomic weight* 69·72. *Specific gravity* 5·91. A greyish-white metal, which in certain lights shows a bluish-green colour. The lustre is metallic. It may be either divalent or

trivalent. Gallium has most unusual properties, melting at 29·75° C. and boiling at 1983° C., thus exhibiting one of the longest liquid ranges of any element. It strongly attacks most solid metals and can be contained successfully at high temperatures only in some refractory oxides, quartz, graphite, and such metals as wolfram and tantalum. A wide variety of uses have been suggested for gallium, ranging from low-melting-point alloys to the treatment of bone cancer. It has useful applications in organic synthesis as a possible heat-exchanging medium to be used for extracting heat from a high level and, because of its low melting point, for use in fire-alarm systems. Gallium increases the hardness of aluminium ternary alloys, and on heat treating will harden magnesium. Gallium may also find a place in electrical contact alloys. (T. 16.)

Galton Whistle. An instrument for producing ultrasonic vibrations of very constant amplitude and frequency.

Galvanic Corrosion. (*Electrochemical Corrosion.*) Corrosion in which two reactions take place simultaneously upon the surface of the metal; metal ions dissolve at areas of high potential and hydrogen ions plate out at areas of lower potential. It can obtain its driving force or potential difference from the use of dissimilar metals, inhomogeneity in a single metal and inhomogeneity in the contacting solution. The basis for comparison of the electrode potentials of metals is the *electrochemical series*. (A. 56.)

Galvanic Series. (See ELECTROCHEMICAL SERIES.)

Galvani, Luigi. (1732–98.) An Italian physicist who discovered the process of generating electricity, chemically.

Galvanism. The science of electric currents. The term is now obsolete.

Galvanized Iron. Mild steel sheet coated with zinc by *galvanizing* in order to protect it from corrosion.

Galvanizing. The coating of steel or iron with zinc, generally by immersion in a bath of zinc, covered with a flux, at a temperature of 425° to 500° C. The zinc may also be electrodeposited from cold sulphate solutions. The zinc is capable of protecting the iron from atmospheric corrosion even when the coating is scratched, since the zinc is preferentially attacked by carbonic acid, forming a protective coating of basic zinc carbonates.

Galvanizing Flux. A solution usually of zinc ammonium chloride, in which steel is immersed before *galvanizing*. It is claimed that the film of flux on the surface of the steel promotes the adhesion of the zinc coating.

Galvannealing. A process in which wire or sheet is passed through a zinc bath and then, without wiping away the excess zinc, is passed through a tube furnace at 650° C. This heat treatment is claimed to prevent the formation of spangles on the sheet and produces a silver-grey matte surface. The coating is mainly alloy. (S. 26a.)

Galvanometer. An instrument for detecting, comparing or measuring small electric currents. A *mirror galvanometer* has a mirror attached to the moving part, a beam of light being reflected from the mirror to a scale, or an image of the scale being observed in the mirror by means of a telescope. The *ballistic galvanometer* is one in which the time of swing of the moving part is long compared with the duration of the transient curve which the instrument is intended to measure. The *vibration galvanometer* is an A.C. galvanometer, the sensitivity of which can be increased by so adjusting its free period of vibration as to agree with the periodic time of the alternating current which is to be detected.

Galvanoscope. An instrument capable of detecting, but not measuring, electric currents. (Cf. GALVANOMETER.)

Galvaprep. A zinc phosphate solution applied to galvanized and other zinc or cadmium surfaces as a base for paint.

Galv Weld. A process of *galvanizing* welds intended for application to localized areas without the trouble of hot dipping large or complicated assemblies. A stick of low-melting zinc-base alloy is rubbed over the heated surface and melts to leave an adherent coating of zinc alloy. It is claimed that this process requires no flux or sand-blasting, makes no fumes, will not peel or chip, and makes a bond to the base metal that is actually superior to zinc metal spray.

Gamagarite. ($Ba_4(Fe,Mn)_2V_4O_{16}(OH)_2$.) A vanadium ore.

Gamma Forming Element. An element, e.g. manganese or nickel, which tends to suppress the alpha phase in steel and to promote the formation of the gamma phase.

Gamma Iron. The *allotropic* form of iron existing between the A_3 and A_4 *transformation points*, which in pure iron occur at 910° and 1405° C.; with the addition of carbon or other alloying elements the position of these points varies. Gamma iron has a *face centred cubic lattice* and is non-magnetic. (See ALLOTROPY.)

Gamma Radiation. (See RADIOACTIVE METALS.)

Gamma Ray Inspection. The method consists of placing a radioactive source at a given distance from one face of the part to be radiographed and a photographic film in a light-proof cassette between intensifying screens against the other face; the whole is left in position for a suitable exposure time, after which the film is developed. (T. 9.)

Gamma Ray Thickness Gauge. A device capable of measuring the thickness of metal from $\frac{1}{16}$ in. up to several inches by absorption of *gamma radiation*. The detector consists of a scintillation counter calibrated in thickness for any given metal. The apparatus is sufficiently robust for use in rolling mills. (I. 18.)

Gammagraph. A *radiograph* obtained by means of *gamma rays*.

Gammagraphy. An American term for inspection by *gamma rays*.

Gamma Rays. Electromagnetic radiations similar to ordinary white light but differing by their wave-length characteristics. They are similar in properties to *X-rays*. Whilst in the former the radiation is produced by radioactive materials, X-rays are produced by high voltage equipment. Radioactive materials may be natural elements such as radium, uranium, and thorium, or artificially produced in nuclear reactors or in cyclotrons. Gamma rays are used for radiography, in a similar manner to X-rays, the sources commonly used being radium, radon, cobalt 60, tantalum 182, caesium 137, iridium 192, and thullium 170. Although the emission of gamma rays is not heterogeneous like the radiation from an X-ray tube, since gamma energy is emitted at certain spectral positions of wave-length, it can be generalized that the radiation from radium, radon, cobalt 60 and tantalum 182 are similar in quality to the radiation from a 2 MeV X-ray unit, whilst caesium 137 is similar to a 1 MeV unit, iridium 192 similar to 600 kV, and thullium 170 similar to about 50 kV. These groups of gamma sources are capable of producing radiographs on 6 to 8 in., $2\frac{1}{2}$ in., 2 in., and $\frac{1}{8}$ in. steel respectively.

Gang Softening. A term applied to the annealing of steel strip when several coils of strip are stacked together in the treatment furnace and heated simultaneously. (Cf. LINE SOFTENING.)

Gangue. The earthy part of an *ore*, i.e. that part which contains no metal.

Ganister. The name originally given to the highly siliceous rock found in the Sheffield district but now applied to any pure and even-grained siliceous rock, which can be used in the finely ground state, bonded with fireclay and water, for foundry purposes. Ganister is also used in the form of bricks for furnace linings in the production of *acid steel*.

Gap-Mill Forging. An operation in which forging is done between rolls, each set of rolls being cut with a series of impressions, into which the work is placed in sequence. The rolls are not complete cylinders, as about a quarter of the periphery is cut away to permit entry of the work. The impressions diminish in size down to the desired final shape. The billet or bar is moved by the operator from one pair of impressions to the next smaller size, and is rotated about 90° each time, so that the flash is squeezed into the bar in each roll forging operation. The part is finally rounded-up and straightened in dies under a steam hammer. (B. 56.)

Gap Voltage. In welding, the voltage between the rod and plate. When a power arc is established the gap voltage is the arcing voltage.

Garnierite. An important nickel ore found principally in New Caledonia. It varies considerably in composition but consists essentially of a hydrated silicate of magnesium and nickel.

Garrett Mill. A rolling mill for the production of rod direct from billets. It was developed by Garrett in 1882, by combining the three-high billet mill with the rod mill and splitting up the latter into three trains of rolls arranged in echelon. These were driven at progressively increasing speeds, so as to rough at low and finish at high speeds.

Gas Blanketed Arc Welding. A method of arc welding metals, which comprises passing an electric welding current between a refractory metal electrode and the work to maintain an arc, passing along the electrode an annular stream of *helium* or *argon* to blanket the arc and molten portions of the work, maintaining the diameter of the stream between 2·33 and 4 times the diameter of the electrode and the length of the stream along the electrode from 4 to 8 times the diameter of the stream with approximately laminar, non-turbulent flow, and maintaining the current within the range having a lower limit between 60 and 150 amperes for a $\frac{1}{16}$ in. diameter electrode and an upper limit between 250 and 1000 amperes, for a $\frac{3}{16}$ in. diameter electrode, thereby stabilizing the arc. (L. 32a.)

Gas Blowpipe Welding. A *fusion-welding* process in which the heat is produced by a gas flame usually oxygen and acetylene unless otherwise specified.

Gas Brazing. (See TORCH BRAZING.)

Gas Carburizing. The introduction of carbon into the outer layers of mild steel by heating it in a current of gas rich in carbon compounds, such as carbon monoxide and/or hydrocarbons or hydrocarbon liquids which break down into oil vapours. The parts to be treated are exposed to these gases in retorts or air-tight furnaces under slight pressure. (F. 49.)

Gas Cavities. (See GAS HOLES.)

Gas Coke. Coke made in retorts as distinct from that made in regenerative *coke ovens.*

Gas Cooled, Silver Finish. (*White to Edge Finish.*) The finish produced when blackplate is annealed in a prepared atmosphere, so that oxidized borders are avoided.

Gas Cutting. (See FLAME CUTTING.)

Gas Cyaniding. Synonymous with *carbonitriding.*

Gas Holes. (*Gas Cavities.*) Spherical holes of varying size with bright walls fairly evenly distributed throughout the section of a casting. The larger holes tend to be found in the heavier section of the casting which is the last to solidify. They are invariably associated with castings having *runners* and *risers* with risen or exuded tops, and they can be distinguished from *blowholes* by the fact that they are more or less evenly distributed throughout the section of the casting. (I. 14.)

Gas Laws. (See BOYLES', CHARLES', and GAY LUSSAC'S LAWS.)

Gas List. An old established price list which originally related to gas pipes but now applies to screwed and socketed tubes and fittings of 6 in. bore and smaller. The word "gas" no longer has any significance.

Gas Pickling. A method of descaling in which the steel is placed in gaseous hydrochloric acid at a temperature of about 750° C. It is claimed that surfaces pickled in this manner give improved adhesion on subsequent *galvanizing.*

Gas Pocket. (*a*) (See BLOWHOLES.) (*b*) A weld cavity caused by entrapped gas.

Gas Pore. A small cavity due to entrapped gas.

Gas Ports. (See PORTS.)

Gas Producer. A cylindrical firebrick combustion chamber for converting coal into gas. Air and steam are forced through a bed of incandescent carbon, which may be coal, coke or other fuel. The fuel is fed in at the top through a *hopper* and the ashes are cleaned out through a water seal. The *producer gas* so obtained consists of a mixture of carbon monoxide and hydrogen with about 50% nitrogen and small amounts of carbon dioxide and hydrocarbons. (T.5.)

Gas Welding. The term covers a group of welding processes in which fusion is produced by heating with a gas flame with or without the use of *filler metal* and with or without the application of pressure.

Gaseous Reduction. The conversion of metal compounds to metallic particles by the use of a reducing gas.

Gases in Steel. The elements *oxygen, hydrogen,* and *nitrogen* are all soluble to a limited extent in liquid steel, and are introduced during the melting process. Some hydrogen may be eliminated on solidification, but all the three gases are usually present when the steel is cold.

Gasflux Process. A *cladding* process in which a steel slab with a scale-free surface is raised to the desired temperature by means of a combustible gas containing a vaporable flux, e.g. methyl borate which is fed into the gas stream, thus depositing a thin film of boric acid on to the steel surface. The fluxed slab is then heated up to about 650° C. and molten copper or copper alloy is poured on its surface. Gasflux is again used at this stage, to flux the steel surface at the steel-copper interface. The slab is then reheated for a few minutes to a few degrees above the melting point of the copper in order to insure complete bonding of the two metals by the migration of iron from the steel into the copper. The composite slab is then reheated to a temperature of 870° to 930° C. and hot rolled to the desired thickness. (T. 45.)

Gassiness. Porosity caused by the evolution of gases during the solidification of the steel.

Gassing. (*a*) The absorption of gas by a metal. (*b*) The evolution of gas from a metal. (*c*) The evolution of gases from an electrode during electrolysis.

Gassiot's Cascade. An electrical apparatus for use with an air pump to illustrate electrical phenomena.

Gassy Ingots. (See OXYGEN IN STEEL.)

Gate. (*a*) (*Geat, Git*). The end of a runner where the metal enters the casting. The term is sometimes applied to the entire assembly of connected channels, to the pattern parts which form them or to the metal which fills them, whilst sometimes it is restricted to mean the first or main channel. (H. 7.) (*b*) In *drop forging,* that portion of the *die* which is cut out to permit a short connection between the impression and the outer edge of the dies. (*c*) (See PASS.)

Gate Shear. (See GUILLOTINE SHEAR.)

Gate Stick. A stick set in the *cope* while it is being rammed to form the passage (*gate*) into the *mould* through which the molten metal is to be poured. (P. 1.)

Gated Patterns. *Mould* patterns designed to permit two or more castings, joined by connecting channels, to be made into one mould. (A. 27.)

Gathering. A defect sometimes found in pack rolled sheets due to a small area of sheet sticking to the roll and hence spoiling the uniformity of the surfaces.

Gathering Stock. Any operation whereby the cross-section of a portion of the stock is increased beyond its original size.

Gathmann Process. A method claimed to produce sound ingots. A thick-walled mould is used, with a thin insulated top, the thick walls extending for about 80% and the thin wall for about 20%, of the length of the mould. The inside tapers sharply at the bottom and the bottom is fitted with a plug projecting through the foundation stool, the whole being placed on a bogie. From the tapered part the walls are practically parallel, with a slight outward taper beginning at 15% to 20% from the top. The advantage is in the rapid chilling of the metal except at the top. (G. 6.)

Gating. A system by means of which a controlled flow of metal into the mould cavity is maintained whilst *risers* act as reservoirs of molten metal to compensate for contraction of the metal on freezing. (See GATE.)

Gating Patterns. The operation of arranging patterns on a backbone so that *sprues* will be formed by the backbone and its connection to the pattern when the mould is made. (P. 1.)

Gauge. (*a*) An instrument for measuring dimensions (e.g. *micrometer* or *vernier*), volumes or pressures. (*b*) The thickness or weight per unit area of sheet and strip or the diameter of rod or wire.

Gauge Length. The specified length, generally 2 in., marked on the parallel portion of a *tensile test piece* on which the elongation is measured. The British Standard tensile test piece has a gauge length equal to four times the square root of the cross sectional area. It is also the active length in the torsion test piece.

Gauge Marks. (See POP MARKS.)

Gaugemeter. A method of gauging continuous strip, in which the rolling mill itself is used as a huge micrometer with the rolls as anvils.

Gauss. (Plural *Gausses*.) The c.g.s. unit of magnetic induction. If a *magnetic field* of 1 *oersted* intensity exists in a medium of unit *permeability*, e.g. air, then the induction will be 1 gauss.

Gayley Process. A method of drying the air to be used for the blast in a blast furnace, by cooling to below freezing point and removing the moisture in the form of ice.

Gay-Lussac. (1778–1850.) Stated law of combination of gases by volume in 1808.

Gay-Lussac's Law of Combining Volumes. The law which states that if gases interact and form a gaseous product, the volumes of the reacting gases and the volumes of the gaseous products are to each other in very simple proportion which can be expressed by small whole numbers.

Gd. Chemical symbol for *gadolinium*.

GDES Specifications. The Government Department Electrical Specifications. Published by H.M. Stationery Office.

Ge. Chemical symbol for *germanium*.

Geat. (See GATE.)

G.E.C. Heavy Alloy. It contains about 90% tungsten alloyed with nickel and copper and is manufactured by *sintering* the metal powders at 1450° C. The alloy is readily machined, is resistant to atmospheric and salt-water corrosion, and may be nickel-chromium or cadmium plated. Used for balancing crankshafts of aero motors, etc.

Geiger Counter. (See GEIGER MÜLLER COUNTER.)

Geiger Müller Counter. (*Geiger Counter*.) A tube which actually counts the quanta of X-ray energy reflected from the sample. It consists essentially of a sealed tube containing an ionizable gas. Energy impinging on the tube causes partial ionization of the gas. The formation of a single ion pair anywhere within the active volume of the counter tube releases a flow of current sufficiently large to operate a relay directly. This current is amplified electronically over a range of 0 to 50 millivolts, which is fed to the high speed recording potentiometer. The recorder scale is evenly divided and is graduated from 0 to 100. (F. 47a.)

Geiger Steel Analyser. An instrument for steel analysis, developed from the Geiger counter. A 20-milliamp 50-kV. molybdenum target X-ray tube is used. The ray floods the steel specimen, exciting secondary rays which are characteristic of the chemical elements alloyed with iron in the sample. These fluorescent rays are reflected through a narrow slit at right angles to the path of the primary X-ray to a crystal monochromator. This crystal is in the centre of a circle, one-fourth of whose circumference is traversed by the Geiger

counter in its round of analysis. The counter is moved by motor in this scanning operation.

Gelling Index. A term used in the evaluation of the characteristics of a clay. The index may be obtained by adding a known weight of the clay to 10 ml. of distilled water in a test tube which is well shaken and left overnight. The minimum amount of clay to give a gel which will then not flow out of the tube when it is inverted is a measure of the gelling capacity, the gelling index being expressed as the value of the ratio weight of water to the minimum weight of clay.

General. (In X-radiation.) Heterochromatic.

General Electric Thickness Gauge. (*a*) An instrument for the measurement of the thickness of electrodeposited coatings which depends upon the change in reluctance caused by a change in the thickness of the gap (or non-magnetic substance) between the measuring head and the magnetic basis metal. (*b*) A thickness gauge using two beams from a single X-ray tube. It is used for strip mill applications.

Generator Gas. (See PRODUCER GAS.)

Geochemistry. The study of the chemical composition of the earth's crust.

Geothermal Energy. Power derived from the heat of the interior of the earth. This has been put into service in certain parts of the world, e.g. in Iceland, the city of Reykjavik receives most of its heat for houses and public buildings from hot springs. In Boise, Idaho, this energy is used for space heating. In the Larderello district of Tuscany, in Italy, geothermic steam generating plants have been constructed with a total capacity of more than 125,000 kw., and in New Zealand explorations are now under way to open and develop great subterranean steam beds to meet the growing demand for electric power.

Gerard Mechanical Gas Producer. In this type of gas producer, the grate, built up of plates, is almost flat, and is protected from the heat of the incandescent materials by a layer of cinders, which are only slowly discharged. The incoming air is well distributed through the joints in the layers of the plates. The rotating body which carries the grate is in the form of a triangular prism with curved faces, each flanked by a semicircular inclined plane. These planes act as ploughs, continually turning up the mass of cinder and fuel. The mechanical gearing of the producer consists of a water-cooled crossbar which revolves in a horizontal plane at a fixed distance from the grate. (I. 42.)

Gerber's Law. A parabolic relationship proposed by Gerber to define the region of fatigue failure for stress cycles imposed on mean loads between zero and the maximum strength. It is expressed by the equation:

$$S_r = S_e \left[1 - \left(\frac{S_m}{S_u}\right)^2\right]$$

where S_r = one-half the total amplitude of the stress range.
S_e = the endurance limit found by the reversed loading test.
S_m = the mean value of the fluctuating stress.
S_u = the static ultimate strength of the metal for the same type of stress.

German Die. A *die*, in which has been machined or gouged a rough impression, used between the flat dies of the steam hammer. Primarily employed to attain a more precise dimension in the forging than can be obtained with flat dies, when investment in production forging dies is not justified.

German Foundrymen's Association. (See VEREIN DEUTSCHER GIESSEREI-FACHLEUTE.)

German Industrial Reports. Published by the *British Intelligence Objectives Sub-Committee*, q.v.

German Silver. (See NICKEL SILVER.)

Germanium. (*Ge.*) *Atomic Weight* 72·6. *Specific gravity* 5·36. *Melting point* 958·5° C. A silver-white, brittle substance, analogous to tin in its physical properties and chemical behaviour. It is usually considered as a metalloid, with properties somewhere between those of a true metal and a non-metal; it is both divalent and tetravalent, the latter compounds being the more stable. The metal is quite stable at 25° C. and is not affected by air, water or oxygen, but at 600° to 700° C. oxidation in air or oxygen proceeds rapidly. Germanium combines readily with the halogens upon heating to form the corresponding tetrahalides. Chlorine reacts most vigorously, followed by bromine and iodine. Hydrochloric and sulphuric acids have little effect at room temperature, but at 100° C. sulphuric acid will dissolve the metal slowly. Both nitric acid and aqua regia will attack germanium, especially at higher temperatures. Potassium or sodium hydroxide solutions have little or no effect but the molten alkalies quickly dissolve the metal. Germanium forms two oxides, GeO and GeO_2. The latter,

germanium dioxide, is the type sold commercially. Most of the germanium in the U.S.A. is produced from by-products of zinc ore. Only in the U.K. has commercial manufacture of germanium been reported as a by-product of the burning of coal. Practically all current production is going into the electronics field where the excellent semi-conductor properties of germanium make it invaluable for use as a crystal rectifier or diode for high frequencies, as a transitor or triode to replace the normal function of the vacuum valve tube, and other devices. (T. 17.)

Germination. Abnormal grain growth in which, under certain conditions, a few grains may grow at the expense of neighbouring grains. (A. 26.)

Germinative Conditions. The presence of a critical amount of *cold work* in a metal, which leads to the development of a very coarse grain structure as a result of heating. (See CRITICAL STRAIN.) (A. 27.)

Getting Down. The further cold rolling of steel strip, after *breaking down* and *annealing*, with the object of still further reducing the thickness before the final cold rolling.

Geveling Process. A method of surface hardening in which heat is generated by the electrical resistance between a roller and the surface of the parts being treated, all deformation of the parts being eliminated. To obtain a good surface finish, a reliable contact between the roller and the surface is necessary. Surface cracks may be prevented by using warm water or an emulsion as a quenching medium. If required, the changes in depth of the hardened layer arising from the mechanism of the hardening process used can be eliminated by low temperature tempering. The depth of the hardened and transition layers may be varied within wide limits.

G.F. Method. A standard method for testing moulding sands, introduced by Georg Fischer, A.-G. Schaffhausen, and widely adopted in Germany.

Ghost. A light coloured streak which when viewed at a suitable angle is just visible on a freshly machined surface. If the surface is left to tarnish slightly, the ghost appears, differing in colour from the rest of the steel. It is due to local *segregation* of impurities, such as phosphorus and sulphur, during the solidification of the ingot, the segregated regions having become elongated during *rolling* or *forging*. The *corner ghost* is usually found at the corners of polygonal ingots, and may even occur in round ones.

Gibbs' Phase Rule. (See PHASE RULE.)

Gilbert. The *c.g.s.* unit of *magnetomotive force*. (See MAGNETOMOTIVE FORCE.) (A. 36.)

Gilbert, William. (1540–1603.) Physician to Queen Elizabeth I. He was the first to discover that a magnet on heating to redness, loses its magnetism. His *De Magnete* was published in London in 1600.

Gilchrist, Percy Carlyle, F.R.S. (1851–1935.) Collaborated with his cousin, *Sidney Gilchrist Thomas*, in the development of the basic *Bessemer process*.

Gill Type E Fatigue Testing Machine. This machine is primarily intended for carrying out tests at high temperatures and is stated to be particularly suitable for investigations of steels and alloys for gas turbine work. Collets in the opposing ends of the shafts for the reception of the test piece are closed by means of sleeves that are bored to provide a light interference fit. The collet shafts are made from an austenitic steel and the sleeves from Nimonic 80, the resulting differential expansion of these metals at high temperatures causing the grip on the test piece to be increased. The collet shafts normally accommodate $\frac{1}{4}$ in. diam. test pieces, but smaller sizes can be supplied if required. (M. 39.)

Gillett, Horace W. One of America's leading technologists, in the development, testing, evaluation and application of metals. He was the first Director of the Battelle Memorial Institute. Died March 30th, 1950.

Gin Furnace. An old form of direct resistance furnace in which the molten steel is contained in a long, narrow trough which is folded backward and forward to form six parallel lengths. The current is led into the ends of the canal by water-cooled steel electrodes which enter from below and form part of the furnace lining.

Girder. A beam, usually a rolled steel section, designed to span an open space and to sustain loads. (See also STRUCTURAL SHAPES.)

Girod Furnace. An old type of electric arc furnace in which the positive pole of a current circuit was connected to one or more carbon electrodes which entered the furnace through the roof, whilst the negative pole was connected to steel electrodes, the upper ends of which passed through the bottom of the furnace and were in actual contact with the metal bath. (B. 23.)

Girond Process. In this process, fluorspar, soda ash, carbon, lime and mill scale were thrown on to the bottom of a hot ladle, and thus sintered. On

tapping the steel from the open hearth furnace into the ladle, the resulting boil removed part of the phosphorus.

Girschig Micro-Sclerometer. (See MICRO-SCLEROMETER.)

Git. (See GATE.)

Gjers, John. (1830–98.) Bessemer Gold Medallist 1894. Gjers was Swedish by birth but came to England in 1851, and remained in this country. His most important contribution was the invention of *soaking pits*.

Gjers Kiln. An old type of kiln used for the calcination of iron ore. It consists of a shell of firebrick cased with iron. The upper part is cylindrical and the lower part is in the form of an inverted cone and is carried on short hollow iron columns between which the charge is withdrawn and the air enters.

Gjers Pit. The original form of *soaking pit* introduced by Gjers in the 1880's. The pit consisted simply of a cavity lined with refractory brick, and little larger than the ingot it was intended to contain.

G.K.N. Micro-Hardness Tester. This instrument can be fitted to most types of metallurgical microscopes, and yields diamond impressions of very small size which can be located to within 0·0002 in. The depth of the impression is extremely small, about $\frac{1}{7}$th diagonal of the indentation which, for a material of 200 VPN using 100 g. load, is only 30 microns. Micro finish of the specimen is essential but special mounting is not usually necessary. (G. 25.)

Gl. Chemical symbol for *glucinium*. (See BERYLLIUM.)

Glancing Angle. The angle between the incident X-ray beam and the crystal planes from which reflection takes place, however these may be inclined to the bounding surface of the crystal; usually written θ. (A. 27.)

Glass Extrusion Process. (See SEJOURNET EXTRUSION PROCESS.)

Glazed Pig. *Pig iron* containing a very high silicon content, e.g. 5%, which gives a very fine grained lustrous fracture.

Glazing. (*a*) A polishing process for iron and steel involving the application of a rapidly rotating emery bob, the abrasive properties of which have been reduced to a minimum. (*b*) The operation of grinding cutlery blades preliminary to finishing. (*c*) Dulling of the cutting particles of an abrasive wheel. (*d*) Fusion of certain constituents on the surface of a refractory material, resulting in the production of a vitreous coating.

GLEEP. Graphite Low Energy Experimental Pile, at Harwell.

Glide. (See SLIP.)

Glide Reflection Plane. (See PLANE OF SYMMETRY.)

Gliding Planes. Planes of preferential shear in the *crystal lattice*.

Globular Powder. Particles having approximately spherical shape.

Globularizing. A balling up of the *cementite* in *pearlite* into globules, brought about by suitable heat treatment. (See SPHEROIDIZING.)

Glo-Crack. A method of detecting cracks in finished steel products, depending on the fluorescence of certain materials when exposed to ultra-violet light. The specimen to be examined is immersed in a special bath of fluorescent material held at a temperature of 75° C. After a short time it is withdrawn and washed in a solution to remove all the fluorescent material from the surface. Should there be any crack in the surface, the fluorescent material remains lodged in it, and, when the specimen is illuminated by ultra-violet light, any crack is shown up with startling vividness against a background of black or purple. The process will not reveal mere scratches with a depth equal to or less than their width. (E. 24.)

Glo-Mor Fluorescent Ink. An ink designed for non-destructive crack detection in stainless steels, non-ferrous alloys and plastics. It depends for its action upon deposition in surface cracks of a material which fluoresces when irradiated with ultra-violet light. As an example of its operation, a test piece is first dipped in the ink, or alternatively a few drops are poured over its surface. After allowing about one minute for the surface to dry, the impregnated test piece is inspected under an ultra-violet light source. Surface cracks then reveal themselves by their brilliant green fluorescence which can be seen even on a background of redundant green fluorescent material. These cracks are sufficiently clearly defined to avoid confusion with tide marks left by the fluorescent ink. Nevertheless, a quick dip in carbontetrachloride is recommended so as to remove the unwanted fluorescing material, while retaining the fluorescence in the cracks. (B. 113.)

Glyco Process. A *composite casting* process, in which the steel bushings to be lined are placed in a tubular container, which is closed at both ends after the required amount of the coating metal has been placed inside. The coating metal is introduced in the form of turnings, powder or small lumps, together with a flux, e.g. borax. The tubular container with its contents is heated in a furnace. When the coating

metal in the container has been melted, the latter is transferred to a centrifuge and rotated until solidification has taken place, i.e. until the steel bushings have been lined with the non-ferrous material. (S. 31.)

Gnome Tester. A portable hardness testing instrument of German manufacture, in which the pressure is applied by screw thrust and the specimen is forced against a ball indenter. The gauge for measuring the load applied is built into the same frame.

Godel Process. A moulding process for grey iron castings, in which a cement-sand is used as pattern sand, and the remainder of the mould is filled up with silver sand. No hand or pneumatic ramming is necessary. (G. 65.)

Goethite. ($Fe_2O_3.H_2O$.) Hydrous ferric oxide.

Gogan Hardness Tester. A type of *Brinell* machine designed for rapid routine testing; 20 to 30 tests per minute are claimed. The principle of the machine depends on the direct indication of the additional depth of penetration effected by a major load after previous application of a minor load, both loads being applied hydraulically and automatically. (A. 61.)

Gold. (*Au.*) *Atomic weight* 197·0. *Melting point* 1063° C. Gold is usually found in the *native* state, but always alloyed with silver or copper and occasionally with traces of other metals. The *tensile strength* of the pure metal is about 7 tons per square inch, and its *elongation* approximately 30%. The density of cast gold is about 19·32, and this can be raised by rolling to 19·48 and by hammering to 19·65. The *malleability* and *ductility* are such that one ounce of the metal may be drawn to give fifty miles of wire. Gold is highly resistant to corrosion by many reagents —hence the fact that it is found native, for example, it is unaffected by nitric, sulphuric and hydrochloric acids, but can be dissolved by aqua regia. Pure gold is 24 *carat* but the usual standard is 22 carat gold, containing 22 parts of gold and 2 parts of alloying metal, usually silver or copper, for the 22 carat gold possesses a greater hardness and wear resistance than the pure gold. In 1798, legislation was passed authorizing an 18 carat gold standard, and in 1854 still lower standards, viz: 15, 12 and 9 carats, were authorized. It was not until 1932 that the 15 and 12 carat standards were abolished and replaced by 14 carat gold. (See also CARAT.)

Golden Arrow Treatment. A surface treatment, which is applied to high speed steel components to improve the cutting efficiency. On completion of the treatment the surfaces have a golden appearance.

Goldschmidt Process. The *alumino-thermic process* of producing metals by reduction of their oxides with aluminium, first developed on a commercial scale by Dr. Hans Goldschmidt in Germany.

Goniometer. An instrument for measuring angles, between crystal faces, or for setting objects in known orientations. *Spectrographs* and *spectrometers* are goniometers of a special kind. (See also INTEGRATING POLE FIGURE GONIOMETER.)

Gooch Crucible. A porcelain crucible, the bottom of which is perforated with numerous small holes, used as a filter in chemical laboratories, the bottom being packed with washed asbestos wool. It is used to increase the speed of filtering, generally in conjunction with a filter pump.

Goodman's Law. A straight line relationship proposed by Goodman to define the region of *fatigue failure* for stress cycles imposed on mean loads between zero and the *ultimate strength.* It can be mathematically expressed by the equation:

$$S_r = S_e \left(1 - \frac{S_m}{S_u}\right)$$

where S_r = one-half the total amplitude of the stress range.

S_e = the endurance limit found by the reversed loading test.

S_m = the mean value of the fluctuating stress.

S_u = the static ultimate strength of the metal for the same type of stress.

(See GERBER'S LAW.)

Goose Neck. (*a*) In a blast furnace, a refractory lined duct which carries the hot blast to the *tuyeres.* (*b*) In a Bessemer converter, a pipe which carries the blast to the *wind box.* (*c*) In a coke oven, the pipe through which the volatile products pass into the collecting main (*d*) (See LADLE).

Gordon-Campbell Moisture Tester. An instrument for determining the moisture content of foundry sands and similar materials. To determine the moisture content a sample is placed on the scale pan to balance the weighing system, as indicated by the pointer in the window. A heat bulb is then brought into position above the sample and heat is applied by turning on the time switch. When the heating period has ended, the current is automatically shut off. When the dial is turned until the weighing

system is again in balance, the moisture percentage will be shown on the dial at the index point. (I. 9.)

Goss Process for the Continuous Casting of Metals. In this process the mould is made up of several sections each with separate cooling. As the metal skin freezes and pulls away from the mould wall a finely divided solid material is introduced through many orifices in the wall. This material remains solid during the casting operation and accommodates itself to the interstices between the cast metal and the mould. This protects the latter from abrasion and helps to conduct away the heat. Provision is also made for sealing off the top of the mould and introducing an inert or reducing gas above the pool of metal. (L. 36.)

Gothic Section. A billet or bar of square section, with slightly convex sides and rounded corners.

Gothite. (See NEEDLE IRONSTONE.)

G.P.M. Gallons per minute.

Grades A, B, or C Iron. Qualities of wrought iron covered by British Standard Specification 51.

Gradient. (*a*) The variation in hardness from the surface to the centre of a casting. (*b*) The hardness gradient of case hardened or surface hardened steels.

Graef Rotor. (See p. 472.)

Graff-Snyder Intercept Method. A means of designating the *austenite grain size* of steel in which the average number of grains intercepted by a line on the specimen surface, having a length of 0·005 inch, are reported.

Graham Process. A development of *stud welding*. The basic principle of the process lies in the discharge from a condenser of a predetermined quantity of energy to form an arc at the base of the stud created by means of an irregular tip which, on coming into contact with the work pieces, fuses, causing ionization and in turn allowing a path for the main discharge. The arc is sufficient to melt both the full diameter of the stud end and the area of the workpiece directly below it. Formation of the arc is immediately followed by a hammer blow of controlled speed and effort, which, in conjunction with the melting of the adjacent surfaces, effects the welding operation. (E. 81.)

Graham's Law. This states that the relative rates of the diffusion of gases under the same conditions are inversely proportional to the square roots of the densities of the gases.

Grain. (*a*) A term used for an *allotriomorphic* crystal present in metals and in one-component alloys. Although a crystal may show division by "*twinning*", etc., it is regarded as the grain rather than smaller subdivisions. In the case of alloys of more than one component, the crystal which, by its transformation gave rise to these constituents, is taken as the grain when its limits are still discernible; if the limits are not discernible the individual constituents are considered as grains. (A. 28.) (*b*) A directional characteristic produced by cold reduction or *pack rolling*. "With the grain" is parallel to the rolling; "across the grain" is at right angles.

Grain Boundaries. The surface separating adjacent crystals of different *orientations*. Grain boundaries interrupt the continuity of the lattice planes and increase the resistance of the metal to cold deformation. Segregation of impurities often occurs along these boundaries. (See also INTERCRYSTALLINE CORROSION.)

Grain Controlled Steels. Steels to which small quantities of *aluminium* have been added to ensure fine grain size.

Grain Fineness Number. The term, as specified by the American Foundrymen's Society, is approximately the number of mesh per inch of that sieve which would just pass the sample if its grains were of a uniform size, that is the average of the sizes of grains in the sample. It is approximately proportional to the surface area per unit weight of sand, exclusive of clay.

Grain Flow. A condition resulting from *hot work*, either *forging* or *rolling*, by which the crystal structure and the *non-metallic inclusions* are elongated in the direction of working, thus presenting a *fibrous structure* or *flow lines*.

Grain Growth. Associated (i) with solidification of a liquid metal when the average size of the grains formed increase inversely with the speed of cooling and the number of nuclei present; (ii) with recrystallization when coarsening of the grain takes place as a result of annealing, the size increasing with the temperature and period of this heat treatment, by boundary migration and the subsequent absorbing of some crystals by adjacent ones, and (iii) with a critical amount of cold working. A tentative theory of the cause of critical grain growth is that with small amounts of cold work there are insufficient centres or nuclei of crystallization to produce any measurable influence on the size of the existing grains after annealing, but with critical intermediate reductions these nuclei are of such a number as to absorb adjacent grains quickly whilst readjustment is

taking place during annealing. With still heavier reductions, nuclei are produced in such large numbers that, on annealing, there is more or less spontaneous recrystallization throughout the mass of metal, and the interference thus introduced prevents any but small or moderate-sized grains from being formed. (P. 29.)

Grain per Gallon. A measure of solution concentration.

Grain Refiner. Any material added to a liquid metal for the purpose of producing a finer grain size in the subsequent casting, or of retaining fine grains during the heat treatment of wrought structures. (A. 27.)

Grain Refining. The term, as applied to heat treatment processes for steel, involves heating from some temperature below the *transformation range* to a suitable temperature above that range, followed by cooling at a suitable rate. Grain refining may also be achieved by hot working with control of the temperature at which the hot working is finished or by suitable cold working and annealing.

Grain Size. This is preferably expressed as the number of grains per unit area of cross-section. The average cross-sectional area of the grain may also be given or the average dimensions. Grain size of strained material is expressed by the average number per linear unit in two directions, or by the average number per unit cross-sectional area, together with the ratio of length to breadth (L/B). By the *Intercept method* for grain count, the number of grains and fractions of grains along a line of known length on two axes at right angles to each other are counted. By the *Planimetric method* for grain count, the number of grains and fractions of grains within a definite area are counted. Evidence has shown the degree to which increasing grain size in a hardenable steel of given composition increases the hardenability and similarly indicates the degree of the superiority with respect to toughness or impact strength of the heat treated steel of fine austenite grain. (See also AUSTENITIC GRAIN SIZE.) (B. 6.)

Grain Size Control. A special deoxidation technique with the object of producing steel having an inherent *austenitic grain size* within a specified range in accordance with the *McQuaid Ehn* grain size scale. It is achieved by the addition of aluminium to the melt in order to reduce the rate at which *austenite* grains grow when steel is heated above the *critical range*.

Grain Size Designation. (See A.S.T.M. COMPARATIVE METHOD OF DESIGNATING GRAIN SIZE.)

Grained Metal. Metal of a fine particle size produced by stirring or otherwise breaking up the metal while it is cooling through the freezing range.

Gram. The unit of *mass* in the metric system. Originally intended to be the mass of 1 cc. of water at 4° C., it is now defined as one-thousandth of the mass of the "International Prototype Kilogram", a cylinder of platinum-iridium kept at Sevres, France.

Gram Calorie. (See CALORIE.)

Gram-Equivalent. The chemical equivalent weight of a substance expressed in *grams*.

Gram Molecule. The quantity of a substance whose mass in grams is equal to its *molecular weight*.

Grand Master Pattern. (See PATTERN, GRAND MASTER.)

Granodine. A zinc iron phosphate coating for use on iron or steel.

Granodizing. A process for producing on zinc or zinc-coated steel, a layer of zinc phosphate by simple immersion in a hot phosphate bath. A final rinse in chromic acid is given to improve the rust proofing properties. *Electro-granodizing* is a similar electrochemical process, and yields a grey-black, velvety coating stated to afford an excellent basis for paint. (T. 34.)

Granodraw. A zinc-iron phosphate coating for iron and steel. It is claimed to improve cold forming and to facilitate drawing operations.

Granolite Treatment. A process of treating piston rings, the object of which is to produce a smooth, relatively soft and slightly porous surface. The treatment comprises dipping the finished-machined rings in a hot bath of dilute phosphoric acid saturated with iron and also containing manganese. When a ring is dipped into the bath a slight attack of the iron takes place, but this soon ceases owing to the deposition on the surface of iron-manganese phosphate. After treatment the rings are dipped in oil. The phosphate coating possesses high oil-retaining properties and is softer than cast iron. (E. 49.)

Granosealing. A process in which a phosphate coating is imparted to iron or steel surfaces, by immersion in a dilute phosphoric acid bath containing manganese at about 100° C., washing in water, and dipping in a soluble oil solution, after which they are dried. It is claimed that such surfaces possess the property of spreading and holding lubricating oil, whilst the wear resistance is considerably enhanced. (S. 90.)

Granular Ash. A form of sodium carbonate.

Granular Fracture. (See FRACTURE.)

Granular Pearlite. A synonym for *divorced pearlite*.

Granular Powder. In powder metallurgy, particles that have approximately equi-dimensional, nonspherical shapes. (A. 27.)

Granulated Metal. Metal in small pellets formed by allowing thin streams of the liquid metal to fall into water. The streams are usually formed by pouring the metal on wire mesh. Another process involves a rotating disc from which the liquid metal is dispersed by *centrifugal force*. (A. 27.)

Granulation. The production of coarse metal particles by pouring the molten metal through a screen into water or by agitating the molten metal violently while it is solidifying. (A. 27.)

Granulometer Separator. An instrument for sorting powders of different sizes (up to 500 microns), based on *Stokes' Law*; the particles fall through an orifice into a series of chambers which pass below it at fixed time intervals. (B. 52.)

Graphidox. A ferro alloy containing about 50% silicon, 10% titanium and 6% calcium.

Graphite. (*Plumbago*.) One of the two naturally occurring forms of crystalline carbon the other being diamond. Specific gravity 2·25. Graphite is present in grey cast iron whilst a variety of graphite produced in malleable castings is called *temper-* or *annealing-carbon*. It is used for foundry facings, and for the production of electrodes, crucibles, etc. *Colloidal graphite* is an excellent lubricant, having high thermal and electrical conductivity, combined with resistance to very high temperatures, and exceptional chemical stability towards most reagents. (See Plate X (b), (c), and (d).)

Graphite Bar Electric Furnace. (*Carbon Bar Furnace*.) The furnace consists of a cylindrical drum in the axis of which is a graphite bar. This is heated with a voltage of about 40 volts up to 2000° to 2500°. The heat radiated against the roof is supplied by a rocking motion to the bath. As the furnace can be sealed easily, current consumption even in small furnace units is relatively low. Graphite-bar consumption amounts to only 3 to 4 kg. compared with 8 to 9 kg. per ton in the electric arc furnace. Due to the highly reducing atmosphere above the bath, the melting loss of alloying elements is very low. (S. 132a.)

Graphitic Carbon. That portion of the *total carbon* in a cast iron which exists as graphite. (Cf. COMBINED CARBON.)

Graphitic Embrittlement. Reduction in ductility of a metal or alloy, associated with the occurrence of graphite in the grain boundaries. (A. 27.)

Graphitic Nitralloy. A steel containing carbon 1·2% to 1·3%, manganese 0·5% approx., aluminium 1·35% to 1·50%, chromium 0·2% to 0·4%, and molybdenum 0·25% approx. It is claimed that nitriding properties are very satisfactory, and that the graphite, where it occurs in the case, acts as a lubricant, and if particles are dislodged the holes act as oil wells. (H. 70.)

Graphitic Softening. The corrosion of grey cast iron, generally due to bacterial attack in which the metallic iron is converted into corrosion products, e.g. iron sulphide, and the graphite is left intact. The sample may appear unchanged but it has become much lighter in weight and is so soft that it can be cut with a knife.

Graphitic Steels. Hypereutectoid steels containing approximately 1·0% silicon. The degree of graphite precipitation is controlled to a large measure by the annealing treatment. After fully annealing, the structure consists of free graphite surrounded by *ferrite* and lamellar *pearlite* typical of a simple steel which has been cooled slowly from a relatively high temperature. Another type of graphitic steel contains 1·45% carbon, 0·75% silicon and 0·25% molybdenum. It is claimed that the presence of graphite gives good machinability and freedom from *galling*. Graphitic steels have been recommended for the manufacture of punches and dies. (B. 68.)

Graphitizing. An annealing process applied to certain iron-base alloys, such as *cast iron* or some steels with high-carbon and silicon contents, by which the combined carbon is wholly or in part transformed to graphitic or free carbon. (See also TEMPER-CARBON, ANNEALING-CARBON and MALLEABLIZING.) (A. 28.)

Graphitizing Elements. Those alloying elements which form solid solutions in cast iron, e.g. aluminium, silicon, cobalt, nickel and copper. (Cf. STABILIZERS.)

Graticule. (*a*) A graduated scale placed in the eyepiece of a microscope. (*b*) A gunsight which may consist of a metal disc having very accurate narrow slots with very sharp corners.

Grating Constant. In crystals, interplanar distance.

Grating Space. In crystals, interplanar distance.

Gravimetric Analysis. A method of

analysis in which the substance to be determined is separated from a solution, in the form of an insoluble compound of known chemical composition, and weighed.

Gravity Die Casting. (See DIE CASTING.)

Gravity Segregation. (See SEGREGATION.)

Grease Mark. A mark on steel sheet caused by oil which has been rolled into the surface.

Greasy Plate. Hot dipped tinplate carrying an excessive amount of residual palm oil.

Greaves-Etchell's Electric Arc Furnace. This furnace is generally worked on a three-phase system, one phase being taken to each of the two vertical electrodes over the bath and the third to the conducting hearth. The conducting hearth is the unique feature of this furnace. The hearth is made by laying a copper plate directly on the shell of the furnace, and the electrical connection is made to this plate. On this plate a layer of graphite, mixed with tar, is rammed into place, whilst over the graphite is a second conductive layer of amorphous carbon. When these two layers are in place the normal refractory bottom is put in. This is generally composed of magnesite or a mixture of magnesite and dolomite bonded with hot tar. After tamping or ramming in position, a bed of coke is placed on the hearth and the current turned on. In this way, the refractory is sintered into place. (H. 6.)

Greek Alphabet. These letters, which are frequently found in scientific and technical literature, are as follows:

Α	α	alpha	=	a
Β	β	bēta	=	b
Γ	γ	gamma	=	g
Δ	δ	delta	=	d
Ε	ε	epsīlon	=	e
Ζ	ζ	zēta	=	z
Η	η	ēta	=	ē
Θ	θ	thēta	=	th
Ι	ι	iōta	=	i
Κ	κ	kappa	=	k
Λ	λ	lambda	=	l
Μ	μ	mu	=	m
Ν	ν	nu	=	n
Ξ	ξ	xi	=	x
Ο	ο	omīcron	=	o
Π	π	pi	=	p
Ρ	ρ	rho	=	rh, r
Σ	σ ς	sigma	=	s
Τ	τ	tau	=	t
Υ	υ	upsīlon	=	ü
Φ	φ	phi	=	ph
Χ	χ	chi	=	kh
Ψ	ψ	psi	=	ps
Ω	ω	ōmega	=	ō

Green. A term usually employed to denote that the material in question has not been subjected to heat, e.g. *green sand*, sand which has not been baked, whilst in powder metallurgy, the term as applied to a compact indicates that it is in the unsintered condition.

Green Copperas. A common name for ferrous sulphate ($FeSO_4.7H_2O$).

Green Core. An unbaked *core*.

Green Deformation. The change in shape which a moist (or green) sand undergoes when subjected to pressure.

Green Density. The density of a compact before sintering.

Green Hole. An American term for a defective tap hole which results in leakage of the molten steel.

Green Plate. Raw plate as received from the rolling mill by the armour plate manufacturer.

Green Rot. A type of corrosion occurring in high nickel-chrome and high nickel-chromium-iron alloys by combustion of industrial gases resulting from carburization and oxidation with formation of Cr_7C_3 below the Cr_2O_3 zone, together with a small amount of nickel oxide. Carburization causes precipitation of Cr_7C_3 with depletion of chromium which reduces resistance to oxidation. The presence of approximately 2% silicon in the alloys will prevent carburization in atmospheres containing both carburizing gases and combined oxygen, because of the nature of the oxide film formed; this forms a barrier, rich in silica, whilst the silica itself seals the rifts in the Cr_2O_3-NiO layer. High-iron alloys of the nickel-chromium-iron type are less susceptible to this corrosion than high-nickel alloys.

Green Sand. (*a*) Ordinary *moulding sand* which has not been baked or otherwise subjected to heat treatment, except by coming into contact with molten metal in the *mould*. The term has no reference to colour. (P. 1.) (*b*) As used in geology, the term refers to a sedimentary sandstone.

Green Sand Match. A false *cope* in which the *patterns* are placed while the *drag* is being made. Its object is to avoid the making of a difficult joint on each mould where there are a number of castings to be made from one pattern. (P. 1.)

Green Strength. The strength of moist sand after shaping. This must be

sufficient for the mould to retain its shape during handling, and in green-sand practice, be sufficient to resist the wash of the molten metal during casting. (D. 9.)

Green Vitriol. (See IRON VITRIOL.)

Greenawalt Process. A system of sintering powdery metalliferous ores.

Greenbat Machine. A horizontal *upsetting* type of hot forging machine. (I. 51.)

Grena. Uncleaned coal or ore.

Grenz Rays. A form of electromagnetic radiation similar to ordinary white light but having a wave-length between that of ultra violet light and X-rays (about 2 Ångström units). They may be considered as very soft X-rays with the ability to penetrate small thicknesses of material opaque to white light. This factor is used in Grenz-ray radiography.

Grey Iron. (See CAST IRON.)

Grey Manganese Ore. (See MANGANITE.)

Grid. (See SKELETON.)

Grindability Index. The ratio of the volume of the material removed in grinding to the volume of the constituent of the grinding wheel removed by wear. The higher this index, the easier the steel is to grind. (T. 4.)

Grinding. (*a*) The operation of removing surplus metal or scale from a surface by means of a rotating abrasive wheel. (*b*) The crushing or pulverizing of materials, e.g. cement, by *ball mill* or other methods. (*c*) A defect caused by the removal of a sliver of metal from the bar during rolling.

Grinding Checks. (See GRINDING CRACKS.)

Grinding Cracks. (*Grinding Checks.*) Cracks caused by too intensive grinding, producing local heating and rapid cooling. They generally occur in the grinding of hardened material such as high carbon or case hardened steels, and appear in the form of network.

Grinding Machine. A machine tool in which flat, cylindrical or other surfaces are finished by the *abrasive* action of a high speed *grinding wheel.*

Grinding Wheel. An abrasive wheel for cutting and finishing metal. It is composed of abrasive powder, such as carborundum or emery, held together by a bond or binding agent, which may be either a vitrified material or a softer material, such as shellac or rubber. Grinding wheels of natural sandstone are no longer permitted in the United Kingdom.

Grip Die. A die in a forging machine designed to hold the stock while the pressure is applied either to form the impression or for *upsetting.*

Grip Marks. Lines or scratches made on the surface of a metal by the jaws of a clamp or other gripping device.

Grips. The shackles for holding the test piece in a tensile testing machine.

Griswold Huet Optical Straight-Edge. An instrument which by utilizing a beam of light as a straight-line reference, measures deviations of supposedly flat surfaces, as small as plus or minus 0·00005 in. It consists of a lens and prism housing and a feeler microscope with built-in illumination which rides along the surface under examination. (G. 56.)

Grit-Blasting Test. This is used for much the same purpose as the *pickling test.* The grit removes the hot-rolled scale so that the surface of the test piece can be visibly inspected. It is not recommended for detecting fine seams on certain types of steel because of the peening action of the grit.

Grizzly. A device consisting of approximately parallel bars used for the coarse separation or screening of ores. (A. 27.)

Grodzinski Microhardness Indenter. An instrument for micro-hardness testing, consisting of a diamond or other hard material, part of which has been polished to a sharp curved edge having at each point an included angle of at least 120° for making the indentation in the test piece, and forming part of the circumference of a circle. The position of the indenter can be changed by means of a slight adjustment if one contact point of the curved edge has become damaged, and no new calibration is required. (G. 58.)

Grodzinski Wear Tester. Apparatus for testing wear and abrasion resistance of hard materials comprising a disc adapted to rotate at very high speeds and a device for holding a specimen against the rim of the disc under small loads for short periods, so as to produce a boat-shaped micro-abrasion mark. (G. 59.)

Groenwall Process. A method of electric production of steel directly from iron ore in which the ore is ground to pea size and roasted in a rotary kiln. The roasted ore is treated in another kiln, where it is mixed with finely-ground coal. The temperature of this kiln is kept at 800° to 900° by means of nichrome resistors placed in the brick lining. From this kiln the materials are charged into an electric shaft furnace and smelted to steel or soft iron. The metal is then refined in an ordinary electric steel furnace, where the composition and quality can be regulated. (G. 60.)

Grog. The name given to previously burnt clay or brick used as an addition in the manufacture of fire bricks. It is ground and incorporated in the clay batch prior to the actual moulding of the fire brick.

Gröndal Process. A method for the direct reduction of iron ores, tried out in 1909, in which rich slimes, together with the necessary amount of powdered charcoal, were fed into the upper end of a long inclined rotary furnace. The gas formed in the reduction was withdrawn at the upper end of the furnace and pumped into a brick regenerator, where it was heated to 800° C. or over, after which the gas was again passed into the furnace at the lower end. During its passage through the furnace the gas gave up the heat it had absorbed in the regenerator. There were two regenerators, one heating the gas, while the other was being heated. This heat was produced by combustion of the gas produced by reduction, together with producer gas from an outside source.

Grönwall Furnace. An electric furnace, developed about the year 1910 by *A. R. Lindblad*, provided with two or more electrodes in the top and one in the bottom, the circuit being made through the heated refractory.

Groove. (*a*) The opening provided for a *groove weld*. (*b*) A depression encircling the body of a roll into which the piece being rolled is forced.

Groove Angle. The total included angle of the *groove* between parts to be joined by a *groove weld*. (A. 37.)

Groove Face. That surface of a member included in the *groove*. (A. 37.)

Groove Planer. An oxy-acetylene torch for cutting U-grooves. It is supplied with three sizes of nozzle for cutting grooves from 3 mm. deep × 6 mm. wide to 8 mm. deep × 6 mm. wide. Its principal application is for cutting grooves for subsequent welding, and the cost of this work is very much less than that of mechanical planing, pneumatic chipping, and grinding. Other applications include cutting splines, spiral grooves, and swages, cutting cracks out of castings and removing weld metal. (G. 57.)

Groove Weld. A weld made in the groove between two members to be joined.

Grossmann Hardenability Chart. A data sheet, the purpose of which is to enable the hardenability of steel to be calculated from its grain size and chemical composition. The first series of curves on the data sheet enables the *ideal diameter* to be read off from the grain size and carbon content, ignoring the other elements (the ideal diameter is the size of bar which would harden through to the centre to a 50% martensitic structure if the surface were instantly quenched to 70° F.). Other curves on the data sheet give the factors for the other elements present, by which the ideal diameter is to be multiplied so as to arrive at the hardenability index for the desired composition. (G. 64.)

Gross Weight. The weight required to produce a single forging. (See also CONSUMED WEIGHT, CUT WEIGHT, MULTIPLE BAR WEIGHT.)

Ground Water. Water derived from wells or springs, as opposed to surface water such as river or lake water.

Growth. (*a*) The permanent increase in volume that occurs when cast iron is subjected to an elevated temperature. It occurs in all grey cast irons and its magnitude depends upon the composition and structural stability of the iron, the temperature of treatment, the time held at temperature, or the length and number of heating cycles and the nature of the atmosphere or medium surrounding the iron. It has been attributed mainly to three causes: carbide decomposition, oxidation, and bursting or cracking caused by expansions and contractions during the $\alpha \rightleftharpoons \gamma$ transformations. (*b*) In powder metallurgy, the increase in dimensions of a compact which may occur during sintering, although normally the tendency is for the compact to shrink. (G. 43.)

Grube Method. A method for the determination of the diffusion coefficient of carbon in alpha iron below 725° C. This method depends on the diffusion of solute atoms in high concentration across an interface into a sample of lower concentration, and depends upon the diffusion of carbon from a high carbon ferrite (high being used advisedly since the maximum carbon is about 0·02% at 725° C., decreasing above and below this temperature) into a carbon free ferrite. If the carbon in the high carbon ferrite is purposely kept lower than the maximum solubility, the diffusion can be checked above (this is an important advantage) and below 725° C. (S. 102.)

Grüneisen's Law. This states that the ratio of coefficient of expansion to specific heat is approximately constant.

Grünewald Process. A process of *bright annealing* in which a vertical cylindrical electrical resistance furnace is used, the coils of wire, strip, and other articles to be treated, being placed in a pot which is inserted in the furnace. No special precautions are taken to exclude air on heating, but when the annealing

operation is almost at an end, a valve in the furnace cover is closed, and cooling takes place in a partial vacuum; in this way oxidation is prevented. By means of air circulation the hot pots may be made to preheat the cold pots, on a recuperative principle. (D. 49.)

Grusz Process. A *composite casting* process, in which the steel backing is heated to a high temperature by immersion in a bath of protective molten salt. After the backing has reached the required temperature, a non-ferrous metal is cast on or in, displacing in the process the protective molten salt layer surrounding the steel backing. (S. 31.)

Guard Plate. A plate placed in front of moving parts of machinery, e.g. brick-making machines, to protect the operatives from injury.

Guards. Devices made of steel or iron employed in rolling mills, mainly on the delivery side of the pass. Guards in conjunction with delivery guides control the direction of the rolled piece as it leaves the rolls.

Gudgeon Pin. A *pin* holding a piston rod and a connecting rod together.

Guerin Process. A method of forming or blanking structural parts in which the metal sheet is forced to conform to the shape of a male *die* by the application of a hydrostatic force of confined rubber. The process was first developed for the forming of duralumin, but its use has been expanded to include the shaping of austenitic corrosion resistant steel sheet of the 18/8 Cr-Ni type. (S. 89a.)

Guide. (*a*) In the foundry, the device used to get the *cope* in the correct position in the *drag*. (*b*) In forging, the portion of a *drop hammer* or press which guides the up and down motion of the ram. (*c*) In the rolling mill, see GUIDES.

Guide Bar. A *cramp bar*.

Guide Mark. (*Guide Score*, *Guide Scratch*, *Guide Shearing*.) Score in the surface of the steel caused by improperly adjusted rolling *guides*.

Guide Mills. (See ROLLING MILLS.)

Guide Pin. (See FLASK.)

Guide Rounds. Round bars which are guided into the finishing pass by means of guides as compared with those that are controlled by hand.

Guide Score. (See GUIDE MARK.)

Guide Scratch. (See GUIDE MARK.)

Guide Shearing. (See GUIDE MARK.)

Guides. The term as used in a rolling mill refers to the steel or iron devices set up on the *cramp bar* to cover the space between each of the working passes, and as the name implies to guide or control the steel as it enters or leaves the rolls. The *entry* or *receiving guide* directs the piece into the pass and the *delivery* or *stripper guide* directs it away from the pass and thus prevents the end of the rolled product following the periphery of the roll and causing a *collar*. *Twist guides* are iron or steel guides with a twist set in them so designed that the bar on leaving the mill twists usually either 45° or 90°. These are used only on continuous mills. *Roller guides* are designed for rounds. They sometimes have windows cut in them and small rollers, shaped to the same shape as the groove in the guide, are inserted. The modification has proved helpful when rolling the larger sizes of rounds because to a large extent it prevents the bars from sticking in the guides. *Roller twist guides* are used for the same purpose as the twist guides but the last few degrees of twist are put on to a bar by means of two small adjustable rollers. These rollers prevent bars being *guide marked* as the steel is being twisted.

Guillenium Effect. (See MAGNETOSTRICTION.)

Guillery Cupping Test. The spherical distending tool of this test has a diameter of 20 mm., as employed in the *Erichsen test*, but the diameter of the *dies* is 50 mm. Load is applied to the tool by hydraulic pressure, a gauge being provided to measure the maximum force of the tool; the test is continued until the pressure reaches a maximum and begins to fall. This end-point is usually more clearly defined than the end-point in the Erichsen test. The size of the test piece, which is clamped tightly, is generally 90 mm. square; both maximum force and depth of cup are recorded. (G. 37.)

Guillery Diamond Indenter. A hardness testing machine. In operation, a preliminary load (pressure) is applied to the indenter through a friction drive; the main pressure is then applied, after which the preliminary load is again applied; the amount of movement of the indenter, as indicated by the friction drive, serves as a measure of the hardness. (G. 68.)

Guillery Hardness Test. A method of hardness testing similar to the *Brinell* but in which the load is applied by means of a spring.

Guillery Impact Testing Machine. This consists of a flywheel having a breaking knife attached to it. This knife is arranged so that it can assume two positions: (1) Flush with the rim of the wheel; (2) Projecting from the rim of the wheel, in which position it is required for breaking the test piece.

The position is controlled by studs operated by centrifugal force, due to the rotation of the wheel. The rotation of the flywheel also operates a small centrifugal pump which elevates a coloured liquid in a tube. The machine is designed so that when the liquid is at the top of the tube (and reading zero on the energy scale) there is 60 kilogram metres of energy in the flywheel. When the flywheel is still and the liquid is at its lowest level the reading is, therefore, 60. The test bar is placed horizontally on knife edges which have a 40 mm. gap. The test is made by rotating the flywheel to a speed slightly in excess of that corresponding to the zero of the energy scale. The gear is then disconnected and the wheel speed allowed to decrease. Immediately the liquid in the tachometer tube reads zero, the "out" stud is pressed, the knife springs out and breaks the test piece. The absorption of energy from the flywheel lowers the speed and the tachometer reading gives the energy lost in producing fracture of the test piece. The knife is then returned by pressing the "in" stud.

Guillotine Impact Testing Machine. An 80 ft. high machine built to develop a maximum impact speed of 100 ft. per second and fitted with a pneumatic gun at the top and an anvil at the bottom. A tup or hammer on which hangs a tension specimen with weight attached, is dropped or fired from the top of the tower. A split anvil intercepts the hammer but the weight falls through an opening; thus the specimen is loaded by the weight pulling at one end, and the hammer bouncing off the anvil at the other. Force-time data are recorded by means of a cathode-ray oscilloscope. (H. 75.)

Guillotine Shear. (*Gate Shear.*) A shear in which the upper blade moves downward, i.e. as a window sash moves down.

Guillotining. Cutting strip to size in a *guillotine shear*.

Guinier-Preston Zones. In a structure precipitating from solid solution, the two dimensional platelets that produce streaks on *Laue* X-ray photograms. These platelets form on specific *crystallographic planes* of the matrix lattice and produce the first discernible evidence of decomposition of a supersaturated solid solution. (A. 27.)

Gun Metal. An *alloy* containing from 89% to 91% copper, 8% to 11% tin, and 1% to 2% zinc. The alloy containing 90% copper, 8% tin and 2% zinc, has a specific gravity of 8·8, and melts at 1010° C.

Gun Method. A method of brazing or soldering done with a so-called "gun" which is used to feed the brazing or soldering wire at some fixed speed which synchronizes with the speed of the workpiece being processed. The speed of the wire as it passes through the gun can be varied to meet the requirements at hand; but, once adjusted to the required speed, maintains that speed indefinitely, and brazing and soldering become a continuous operation. (B. 76.)

Gunite. A concrete or mortar protective coating applied by means of a cement gun, to protect structural steel against corrosion or fire.

Gurlt Process. A method for the direct reduction of iron ore (1857), which made use of a shaft furnace. The shaft was charged only with ore, and reduction was carried out with gas from producers. In order to attain a sufficiently high temperature, a small part of the gas was burned, before passing into the reduction shaft, with air which was blown in through channels.

Gussev. (See ELECTROLYTIC TOOL SHARPENING.)

Gussolit Welding Process. A method for the reconditioning of defective metal parts. It is stated that the part to be treated is raised to a temperature of from 850° to 900° C., coated with a special flux, and Gussolit welding rod melted into the crack or defect. During the melting of the welding rod, the flame is made to play in a direction parallel to the surface of the work in order to prevent excessive heating of the metal. (E. 42.)

Gustafsson Machine. A machine for the application of repeated impact bending. A round specimen, one end of which is rigidly clamped, receives alternate blows at its upper end from two pendulum balls falling from opposite directions. These balls are raised mechanically to the position from which they are released. The speed of operation is 50 double blows per minute. (G. 36.)

Gutter. (See GUTTERING.)

Guttering. In *drop forging* practice, as all excess metal or *flash* is forced out round the impression, it is necessary to sink the dies to allow this excess to flow into a recess or *gutter*, thus allowing the die faces outside the impression to *rap* when the stamping is down to thickness. The provision of this recess is referred to as guttering.

Guy Rope. A rope for holding a structure in position.

Gypsum. A mineral consisting of calcium sulphate ($CaSO_4.2H_2O$).

H

H. (*a*) Chemical symbol for *hydrogen*. (*b*) *Hardenability*. (*c*) Abbreviation for horizontal-vertical welding position.

H Band Hardenability Specifications. The ordering of steels, especially alloy steels for motor car production, by reference to the degree of hardenability. (See H STEELS) (U.S.A.)

H Beam. (See STRUCTURAL SHAPES.)

H Steels. (*H Band Hardenability Specifications*.) Steels made to certain American Iron and Steel Institute Specifications which cover *hardenability* without reference to chemical composition. (S. 122.)

Habit. A term used to cover the varying development of the crystal forms possessed by any one mineral. Thus, calcite may occur as crystals showing the faces of the hexagonal prism, basal pinacoid, scalenohedron, and rhombohedron. According to the relative development or dominance of one or other of these forms, the habit may be prismatic, tabular, scalenohedral, or rhombohedral.

Hadfield Ingot Process. A method for producing steel which consists in the use of a sand-lined sinking head on top of the ingot mould in which the steel is maintained liquid by the combustion of solid fuel (charcoal or coke) by means of a blast of compressed air, a layer of cupola slag being interposed between the liquid steel and incandescent fuel The slag largely prevents radiation of heat. The discard is said to amount to not more than 7% of the ingot. (H. 3.)

Hadfield, Sir Robert Abbot, Bart., D.Sc., F.R.S. (1859–1940.) The inventor of austenitic *manganese steel* (1882) and of silicon steel (1884) and responsible for numerous other researches.

Haematite. (*Bloodstone*.) (Fe_2O_3.) An important high-grade iron ore varying in colour from black to blood red. Although consisting essentially of iron sesquioxide, it may be associated with sand, clay or the oxides of other metals such as titanium or magnesium.

HAE Process. An electrolytic process which produces a hard non-metallic seal on metallic surfaces. (F. 41.)

Hafergut Method. (See FIRECRACKER WELDING.)

Hafnium. (*Hf*.) *Atomic weight* 178·6. *Specific gravity* 13·31. *Melting point* about 2310° C. A metallic element. All zirconium minerals contain an appreciable quantity of hafnium and the chemical characteristics of the two metals are so similar that there is considerable difficulty in separating them. The main difference is that the density of hafnium is about twice that of zirconium. Hafnium has as yet found no commercial application. (R. 46.)

Haigh Fatigue Testing Machine. This machine is fitted with a pair of opposed two-phase alternating current magnets which pull an armature first towards one magnet and then towards the other. One end of the specimen is attached to this armature and the other to the framework of the testing machine. Stress is controlled by varying the current flowing in the magnets, and *load* (and consequently stress) is measured by the *electromotive force* induced in auxiliary coils wound on the magnet cores.

Haigh Prism Test. A hardness test in which two square prisms, placed crosswise with their edges in contact, are pressed together by a measured load. The prisms are supported on two blocks cut with 90° V-grooves to suit square test pieces, and guided so that the cutting edges of the two prisms cross one another at right angles. The guides are a pair of steel pins, screwed into the lower block and working through long brass bushes in the upper block. To minimize friction and ensure axial loading, the load is applied through a ⅝ in. steel ball that rests in spherical seatings in the upper holder and cap. The test is carried out in a small compression testing machine. (H. 5.)

Haigh Robertson Fatigue Test. In this test, a wire specimen is rotated under load, and every point round the periphery is in turn subjected to the full range of stress One end of the wire is held in a chuck driven by a small motor, the chuck and motor being capable of swivelling about a vertical axis through the point where the wire emerges from the chuck. The other end of the wire is supported within a ball thrust bearing, movement of the latter, parallel to itself, towards the chuck causes the wire to form a bow, the chuck and motor swivelling to accommodate this flexure. (E. 40.)

Hair Line Cracks. (See FLAKES.)

Hair Lines. Defects resulting from the rolling out of small surface inclusions along the helical path of the motion developed in the rotary piercing operation. They are removable by light dressing, being usually confined to the external surface. (Cf. HAIR LINE CRACKS.) (L. 28.)

Half Hard. (See TEMPER.)

Half Tone Block. A printing plate for photo-engraving by means of which

intermediate tones between black and white can be obtained.

Half Tone Process. A method of photographic reproduction in which the tones of the original are shown as dots of uniform tone but varying size. This dot image is etched on to metal producing a *half tone block*.

Halides. The binary salts—*fluorides, chlorides, bromides* and *iodides*, formed by the union of a *halogen*: fluorine, chlorine, bromine or iodine with a metal, e.g. NaCl, KBr.

Hall-Adeline Process. (See ADELINE STEELMAKING PROCESS.)

Hall Coefficient. The transverse electric potential gradient set up in a conducting strip, exhibiting the *Hall effect*, per unit *current density* per unit *magnetic intensity*.

Hall Effect. The potential difference created between two edges of a metal strip carrying a longitudinally flowing electric current when the plane of the strip is placed perpendicularly across a *magnetic field*.

Hall, Joseph. A native of Staffordshire, who introduced wet puddling about the year 1820, the process later becoming known as the *pig boiling process*.

Hall Process. The usual process of winning aluminium from alumina by electrolytic reduction of a fused bath of alumina dissolved in cryolite. (A. 27.)

Halloysite. A massive claylike or earthy material used as a bond in certain types of green *sand moulding*. It is *isotropic*, has a conchoidal fracture, and often resembles unglazed porcelain. (A. 26.)

Haloes. Circular, silver coloured, defects sometimes seen in the tensile fractures of mild steel weld metal samples.

Halogens. The elements fluorine, chlorine, bromine and iodine.

Halometer. An instrument for measuring the forms and angles of salts and crystals. (See GONIOMETER.)

Halt in the Gauge Method. (See YIELD POINT.)

Hamasumi High Temperature Hardness Tester. A vacuum high temperature hardness tester, consisting of a double-walled glass cylinder, the inner cylinder being graduated on the surface for measuring the height of rebound of a ball. A small heating furnace is hung in the glass cap, which fits on the outer cylinder. The test ball is hung at a constant height by a fine manganin wire in the furnace, the temperature of the furnace being determined by a thermocouple. The manganin wire is severed electrically at any desired temperature. The ball drops on to a cast iron anvil and the height of the rebound is measured by the scale on the inner cylinder. (H. 10.)

Hametag Process. A method used in Germany for the production of relatively fine iron powder. In this process, steel (containing 0·5% manganese, added to improve the drawing properties) is drawn into wire, cut into small pieces, and milled. (M. 142.)

Hamilton-Evans Process. A method of producing high chromium steels of the stainless class where a high chrome slag is formed over a low carbon steel, using lime and chrome ore, the chromium being finally reduced into the steel by the use of *ferro-silicon*. (I. 65.)

Hammer. (See TILT HAMMER.)

Hammer Burst. (See HAMMER PIPE.)

Hammer Cogging. (See COGGING.)

Hammer Forging. (See FORGING.)

Hammer Lap. A defect on the surface of steel, being a folded-over portion produced by bad practice in forging.

Hammer Pipe. (*Burst, Split Centre.*) A central hole or discontinuity occurring axially along forged sections, due to improper forging and not to segregation.

Hammer Refining. (*Mechanical Refining.*) The operation of hot working steel by hammer or press in order to obtain grain refinement.

Hammer Scale. The layer of iron oxide which forms on iron and steel when heated for forging.

Hammer Slag. Slag expelled from the ball of iron in the *puddling process* by hammering or squeezing.

Hammer Welding. A *forge welding* process, in which fusion is obtained by mechanical pressure (*hammering*) at high temperatures.

Hammered Resistance Welding. A process for the welding of tubes which is a combination of electric resistance welding and hammering. The current is supplied by a pair of disc electrodes mounted on one shaft but insulated from each other, and there is a pneumatic or electrically operated hammer between the electrodes and above the edges to be joined; this makes rapid blows on the weld as it is heated and fused together, an action which can be continued during the cooling cycle if desired. (P. 20.)

Hammering. (*a*) In the *puddling process*, compacting a spongy puddled ball to a solid bloom by forging under a hammer. (See SHINGLING.) (*b*) Beating metal sheet into a desired shape either over a form or on a high speed mechanical hammer, in which the sheet is moved between a small curved hammer and a similar anvil to produce the required dishing or thinning.

Hanbury, John. (1664–1734.) The inventor of sheet iron rolling. It was in 1728 that he devised the method of rolling plates by means of cylinders.

Hand Bar Mill. (See ROLLING MILLS.)

Hand Files. Files which are parallel in width but from about two-thirds of the length taper thinner to the point. One edge is *safe* and the other cut. These files are not so named because they are made or used by hand.

Hand Forging. (See SMITH FORGING.)

Hand Rammer. A foundry tool with a rounded head at one end and a wedge-shaped head at the other. It is used for packing sand round a pattern.

Hand Rounds. Round bars which are guided into the finishing pass by means of hand tools.

Hand Shank. A two-man ladle.

Handling Holes. Holes drilled in opposite ends of a *die block* so that it can be moved by means of a crane or bar.

Hanemann Micro-Hardness Tester. In this instrument the diamond pyramid is located in the front lens of the objective. The diamond pyramid has a diagonal of 0·8 mm. and a sufficient annular area of the lens is left for lighting and photographing the object. A device is built in for generating and measuring the test load. (D. 34.)

Hanger Crack. (See HEAD PULL.)

Hanging. A term applied to a *scaffolded* blast furnace, owing to the fact that the charge does not descend normally.

Hankins Scratch Hardness Tester. In this instrument, the test piece is clamped to a block either horizontally or at the angle of the block. The diamond holder is fixed in a rod that is free to move vertically in the bridge of the apparatus, and the orientation of the diamond is also fixed. Weights are placed on the top of the rod to which the diamond is fixed, and the latter is slowly lowered on to the test surface. A scratch is then obtained by turning the leading screw of the block to which the test plate is clamped. The microscope used for the measurement of the scratches is fitted with oil immersion objective and travelling wires in the eyepiece. (H. 16.)

Hannifin Quenching Machine. A machine for centrifugally quenching circular parts, such as gear and sprocket wheels, in which the principle of quenching the heated circular part from the periphery towards the centre is applied, and all parts of the periphery are immersed in the cooling oil at the same time. The quenching chamber contains adjustable supports on which the rim of the wheel to be hardened rests and rams can be made to exert pressure on the wheel centre from above or below to correct any distortion. The chamber is spun on a vertical axis, and the cooling oil enters it over a deflector plate which directs it to the chamber wall; centrifugal force causes the oil to build up with a vertical surface, and this surface approaches and passes over the periphery of the wheel as more oil is pumped into the chamber. The quenching time, the volume of the quenching medium and its temperature can all be controlled. (E. 50.)

Hanson-Munning Process. A method of bright-dip pickling, developed to deal with alloy steels, especially chromium-nickel steel. The plant consists of two dipping tanks, the first of which contains an acid solution maintained at a temperature of from 50° to 65° C. by means of a steam coil. From the electrodes to the work, a current of 100 amp. per sq. ft. of surface to be cleaned is maintained at a pressure of 6 volts. The acid solution contained in the second tank is maintained at a temperature slightly lower than that of the first tank. In the second tank the current flows from the work to the electrodes and is maintained at 150 amp. per sq. ft. of surface at a pressure of 6 volts. (S. 106.)

Hard Carbides. The hard carbides consist chiefly of the carbides of metals from Groups IV, V and VI of the Periodic Table, namely titanium, vanadium, chromium, zirconium, niobium, molybdenum, hafnium, tantalum, and tungsten, and because they have high melting points, they are difficult to prepare in the pure state. They are extremely hard and possess the metallic properties of lustre and high thermal conductivity to a marked degree. Alloys are formed by these carbides in two ways: (1) with metals, particularly of the iron group, and (2) with each other, forming solid solutions. (Cf. HARD METALS.) (G. 3.)

Hard Direction. (See ANISOTROPY.)

Hard Drawn Steel Pellets. (See CUT WIRE SHOT.)

Hard Drawn Wire. Wire drawn from rod which has been subjected to a reduction of area greater than 10%.

Hard Facing. A technique by means of which a protective coating can be welded on to almost any wearing part. The welded materials used are selected according to the properties required, e.g. corrosion resistance, wear resistance, or low coefficient of friction. Parts to be hard faced are preheated, the rate of cooling after welding being controlled. Design must be such that distortion upon heating and cooling is minimized.

Surface cracks which sometimes occur on cooling may be minimized by suitable selection of the parent metal and welding rod, and by attention to heating and cooling rates. The thickness of hard facing may be varied to meet requirements. Hand welding with the oxy-acetylene torch is superior to arc welding, the rate of application being higher, and the deposit obtained being smoother, more uniform and free of porosity. (W. 17.)

Hard Head. A tin-iron alloy obtained in the smelting of slags from the first treatment of tin concentrates in either the *blast furnace* or *reverberatory furnaces*. (A. 27.)

Hard Metals. (*Cemented Carbides.*) Powdered carbides of tungsten, tantalum, or titanium, cemented into solid masses by mixing with powdered cobalt or nickel, then cold pressing and sintering. Used for cutting tools, wire drawing dies, and parts subjected to heavy wear or abrasion. (See POWDER METALLURGY.)

Hard Setting. The provision of a hard metal insert, e.g. tungsten carbide, to the wearing surface of a part or cutting edge of a tool. This may be followed by the application of a hard surfacing alloy.

Hard Soldering. (See SOLDERING, SILVER SOLDERING.)

Hard Spelter. (See SPELTER.)

Hard Spots. Areas of excessive hardness caused by micro-structural segregations such as carbides and other hard phases or by localized rapid cooling or by burnt-in pieces of moulding sand; a condition sometimes found in poor quality castings. The machining tool in passing over these areas does not cut properly and gives a raised and usually a glazed surface.

Hard Surfacing. Various methods are employed for producing a hard surface on steel. They include *carburizing*, *nitriding*, *Chapmanizing*, *dry-cyaniding*, *Ni-Carb process*, *induction hardening*, *flame hardening*, *metal spraying* and *fusion welding*. (B. 33.)

Hard Temper. (See TEMPER.)

Hardenability. The property that determines the depth and distribution of hardness induced by quenching. It is generally expressed in relative terms and is related to the *critical cooling rate*, i.e. the rate at, or above which, wholly *martensitic* structures are formed. This critical cooling rate, or hardenability, is largely a function of composition, although steels of apparently similar composition can have different hardenabilities and the same cast of steel may show fairly wide variations. There is a limit to the section size which can be completely hardened upon quenching. Plain carbon steels are comparatively shallow hardening, and alloy additions increase the depth of hardening. (See also RULING SECTION.) Steels with the same end-quench hardness curves may vary considerably in toughness, as measured by notch-bar tests at equal hardness and strength levels. This is true even though the steels may retain substantially equal amounts of austenite after the quench. (F. 47.)

Hardenability Bar. A centre-quenched test bar for shallow hardening steels, which is simpler than those needed for the *cone test* and *Jominy L-Bar test*. It consists of a plain cylinder 2 in. long and 1 in. diam. with a longitudinal hole drilled off-centre to give a varying wall thickness. In the hardenability test, the specimen is quenched by pumping water through this hole, the ends of which are chamfered to receive the nozzles of the quenching apparatus. After quenching, the bar is sectioned transversely at its mid point and hardness readings are taken in a circle concentric with the periphery of the bar and $\frac{1}{16}$ in. from it. (E. 2.)

Hardenability Curve. (See JOMINY TEST.)

Hardenability Test. (See JOMINY TEST.)

Hardeners. *Master alloys* prepared for the purpose of adding small quantities of the desired alloying elements to molten metals.

Hardening. Increasing the hardness by *heat treatment*. This term, used without qualifications, usually implies heating to a temperature slightly above the *critical range*, i.e. above the Ac_3 point, maintaining at that temperature until diffusion is complete, and quenching in water, oil or air at a rate which is sufficiently rapid to prevent or retard the *austenite/pearlite* transformation, and to form a martensitic structure. The minimum rate of cooling which will achieve this is termed the *critical cooling rate*. This definition does not, of course, apply to *austenitic steels*. Moreover, there are many other methods of hardening, e.g. *carbon case hardening*, *nitriding* and *cold working*. (See Plate VIII(d).)

Hardening Crack. A quenching crack.

Hardening Metals by Rotating Magnetic Fields. A method of increasing the hardness of a magnetic metal by applying an artificial atomic disturbance, such as might be caused by a magnetic polarity of changing direction. (H. 43.)

Hardenite. (*a*) The term applied by *Arnold* to the eutectoid in the iron carbon equilibrium diagram, i.e. *pearlite*

after it had been heated and quenched to give it the maximum degree of hardness. The term is now obsolete and has been replaced by *martensite*. (*b*) *Caron's Cement*.

Hardness. Signifies, in general, resistance to deformation. It is actually measured by determining the resistance to indentation, as in the *Brinell, Diamond Indenter, Rockwell, Herbert* and *Shore* tests. The values of hardness obtained by the different methods are to some extent, but not entirely, related to each other, and to the ultimate tensile stress of non-brittle metals. (See also MOHS' SCALE and ABSOLUTE HARDNESS.)

Hardness Comparator. There are several instruments of this type on the market, all working on the same principle. A hard steel ball usually 10 mm. diameter is placed between the surface to be tested and a standard test bar which is then given a blow with a hammer. From the size of the two indentations the maximum load of the blow, and hence the Brinell hardness of the tested surface, can be ascertained. Usually a chart is provided from which the hardness is read off directly from the value of the two impressions. This form of test whilst not very accurate, is sometimes useful, for example, for testing large masses difficult to test by other means. (W. 68.)

Hardness Testing Hammer. The operation of this instrument is similar to the *Auto Punch*. It is equipped with a Brinell penetrator and can be adjusted to read in terms of Brinell hardness numbers. (W. 14.)

Hardometer. (See FIRTH HARDOMETER.)

Harman Process. A method for producing direct from ore an iron in the form of either sinter or pig which is suitable for charging in steel furnaces. Ore, limestone and carbon in the form of coal, coke or oil coke in the proportions 40/8/5 are dried, crushed to about $\frac{1}{16}$ in., intimately mixed, and fed into the upper end of a sloping rotary kiln. As the material advances through the kiln it is heated by a reducing atmosphere, the solid carbon in the charge reducing the ore; in this stage of the process there is no excess of carbon to reduce the silica in the ore, which combines with calcium in the limestone to form silicates. Further down the kiln the material is impregnated with additional carbon, sintered, and then discharged into a vertical cylindrical melting furnace. The carbon in the product is controlled by carbon additions made directly to the metal below the slag in the melting furnace. The slag in this furnace is basic, with a lime content of 40% or over. The sinter falls through a short shaft into the centre of the bath, in which a reservoir of about 18 in. of metal is maintained at all times. (H. 18.)

Harmet Process. A method of producing steel ingots in which pressure is applied during solidification of the steel in the ingot mould. The advantages claimed for the Harmet method are the avoidance of axial unsoundness, a finer structure in the middle of the ingot and the prevention of marked segregation in the direction usually followed when freezing proceeds normally. (K. 49.)

Hart Process. An accurately timed electric resistance process for welding two tubes or a tube and another article in such manner that there is no *scarf* to be removed afterwards. It consists of three major steps: reinforcing the tube ends; preparing the ends for welding; and the welding operation itself. (W. 41.)

Hartmann Gas Current Generator. A device to produce ultrasonic waves. (H. 24.)

Hartmann Lines. (See PIOBERT EFFECT.)

Hartshorn. (See SPIRITS OF HARTSHORN.)

Harveyizing. A method of treating heavy steel plate to be used for armour plate. It consists of a case hardening process by which the carbon content of the face of the plate may be raised to 1.5%, this being achieved by heating the plates in contact with finely divided charcoal for a period of about two weeks. The treated plate, which may be as much as 18 in. thick, is then hardened by quenching in oil or water.

Hatfield Intercrystalline Corrosion Test. (*Weld Decay Test.*) The accepted test for resistance to intercrystalline corrosion of the austenitic corrosion resistant steels. A test piece, before submitting to a bend test, is heated at a temperature of 650° C. for 30 minutes and cooled in air. The test piece is then immersed for 72 hours in a boiling solution having the composition: 111 grams of copper sulphate, 98 grams of sulphuric acid, made up to 1 litre with distilled water. The test is sometimes erroneously referred to as the *Strauss*, or *Krupp Solution Standard I.C. Test*, but these are misnomers as it was developed by Dr. W. H. Hatfield at the Brown-Firth Research Laboratories.

Hatfield Time-Yield. A short time creep test criterion. The specimen placed under the time-yield stress should not show an extension exceeding 0·50% of the gauge length in the first 24 hours, and during the next 48 hours should show no further extension, within a sensitivity of measurement of 1/10,000th in. on a 2 in. gauge length, which is

approximately equivalent to a rate of creep of a millionth of an inch per inch per hour during this period.

Hatfield, William Herbert, D. Met., F.R.S. (1882–1943.) An English metallurgist whose earlier investigations were concerned with the reactions involved in acid open hearth steelmaking. For a time his interests turned to the metallurgy of cast iron, but his name is most strongly linked with the development of corrosion- and heat-resisting steels, including pioneer investigation of the problem of *intercrystalline corrosion*.

Hausmannite. (*Black Manganese.*) A manganese ore consisting essentially of manganese oxide, Mn_3O_4.

Hauttman Hardness Tester. An instrument in which a ball is freely suspended and rolled at constant load over the specimen that moves on a slide beneath the ball at a specified velocity. Width and depth of the trace left by the ball on the specimen are used as an indication of Brinell hardness caused by cold rolling. The machine can also be used for testing variations in hardness as a function of time. (H. 32.)

Haveg. A corrosion resistant material recommended for chemical plant construction. It is a mixture of asbestos with a high silica content, and *bakelite*, a synthetic resin. It has a structure similar to wood, and is stated to resist temperatures up to 200° C. It is not affected by dilute hydrochloric or sulphuric acids. It is not resistant to alkalis or nitric acid

Hazelett Process. A method for casting liquid metal or steel continuously into rolls for sheet or plate. The steel is poured on to the outer surface of a broad steel cylinder of very large diameter (up to 6 m) which is supported and revolved by a roller turning inside it The molten steel is carried a short distance to a roller revolving above the ring, which rolls the almost solidified steel into a thin plate or strip. (N. 1)

HBr. Chemical formula for hydrobromic acid.

Hc. Coercive force.

Hci. *Intrinsic Coercive Force.* (See COERCIVE FORCE.)

H.C.P. *Hexagonal, Close Packed.*

Hcr. *Relaxation Coercive Force.* (See COERCIVE FORCE.)

HD. Symbol for diamond hardness.

He. Chemical symbol for *helium*.

Head. The pressure exerted by a fluid as a head of steam or of molten metal. (A. 26.)

Head Metal. A term used in the foundry for the reservoir of metal in the *feeder* of a *mould*.

Head Pull. (*Hanger Crack.*) A crack caused by restriction of an ingot during cooling, the restriction being caused by the suspension of the ingot in the mould, due to a badly fitting feeder head.

Header. (*Header Course.*) A layer of brick which is laid with the ends towards the face of the wall. (A. 26.)

Header Course. (See HEADER.)

Healing. The welding up of cracks, formed during the first few passes, by further hot rolling.

Heap Sand. *Green sand* from the foundry floor.

Heart and Square. Moulder's heart-shaped trowel.

Hearth. (*a*) In the blast furnace, that zone at the bottom of the furnace into which the molten *pig iron* trickles down and collects until it is tapped off. (*b*) In an *open hearth*, or *electric arc furnace*, that part of the furnace in which the steel is melted.

Heat. (*a*) A form of energy which when given to a body raises its temperature. (*b*) The steel melting operation from the charging of raw materials, to the tapping of the molten metal. (*c*) The batch of steel produced by a single melting operation. (See CAST.) (*d*) In forging, the period of working before reheating becomes necessary. (*e*) The amount of forging stock heated up at one time.

Heat Affected Zone. The zone consisting of the *parent metal*, adjacent to the weld, which has been changed in structure and properties by the heat induced by the welding operations.

Heat Capacity. (See THERMAL CAPACITY.)

Heat Checking. The formation of *thermal cracks*.

Heat Etching. A method for revealing the *austenitic grain size* of any steel and particularly of steels containing less than 0·10% carbon. The polished specimen is heated at a suitable temperature in an inert atmosphere where the metal at the *grain boundaries* is preferentially vaporized, thus revealing the austenitic grains. Oxidation of the etched surface is prevented by quenching the specimen in a mercury bath, out of contact with air.

Heat Exchanger Tubes. Tubes used in a unit for the purpose of transferring heat from one medium to another.

Heat Flow Meter. A small disc of tellurium-silver alloy with copper gauze coating on its two sides. This is placed with its plane at right angles to the flow of heat to be measured, creating a small proportionate difference of temperature between the two sides. The disc is connected by fine wires through a terminal block to a galvanometer which registers the thermal *e.m.f.* due

to difference in temperature of the two tellurium-copper junctions. (H. 26.)

Heat of Adsorption. Quantity of heat evolved in adsorption of a definite quantity of gas on a bare surface.

Heat of Combustion. The amount of heat evolved when one gram-molecule is burned in oxygen at constant volume.

Heat of Crystallization. Heat evolved when unit weight of a salt crystallizes from a large amount of a saturated solution.

Heat of Dilution. The quantity of heat absorbed or evolved upon diluting a solution with water, or upon mixing a strong solution with a weaker solution of the same substance. It is usually expressed as B.Th.U. per pound, or calories per kilogram.

Heat of Formation. The quantity of heat liberated or consumed when a compound is formed from its component elements.

Heat of Fusion. The heat required to convert a definite quantity of a substance from solid into liquid without change of temperature.

Heat of Hydration. The quantity of heat liberated or consumed when a substance takes up water.

Heat of Ionization. The quantity of heat that is absorbed when one gram-equivalent of a substance is broken up completely into positive and negative ions.

Heat of Linkage. The energy necessary to break a chemical bond.

Heat of Mixture. That quantity of heat evolved when two liquids which do not react together are mixed. It is calculated from the temperature change and the specific heat of the mixture, and expressed in gram-calories per gram of mixture.

Heat of Neutralization. Amount of heat evolved when one gram-equivalent of an acid is neutralized by a base.

Heat of Reaction. Quantity of heat evolved when the reaction takes place at constant volume, in the direction indicated by, and between the amounts of substances represented in a chemical equation

Heat of Solution. The quantity of heat liberated or consumed when a solid is dissolved in a liquid.

Heat of Transformation. The quantity of heat accompanying a constitutional change in a solid chemical compound or metal, e.g. the change from *gamma* to *alpha* iron. The temperature at which one crystalline form of a substance is converted into another solid modification is known as the *Transition Point* or *Transition Temperature*.

Heat of Wetting. Heat evolved or absorbed when a liquid and a solid surface are placed in contact.

Heat Refining. Reheating steel to about 50° C. above its critical range, and cooling rapidly, with the object of obtaining a fine grained steel.

Heat-Resistant Steels. Steels which, by the addition of alloys, are able to resist oxidation (scaling) at elevated temperatures, and which also retain at such temperatures a greater proportion of their normal strength than ordinary steels, i.e. *creep resistance*.

Heat-Resistant Cast Irons. For service at temperatures above 400° C. the quality of cast iron is evaluated by its resistance to oxidation and growth. Small additions of molybdenum improve the high temperature strength and, in combination with chromium, reduce the susceptibility to oxidation and growth. Various austenitic cast irons have been developed for high temperature service. These irons may contain from about 12% to 20% nickel, 1·5% to 4·0% chromium with or without up to 7·0% copper and variable silicon. The combined effect of the nickel, chromium, carbon and silicon is to produce a structure which presents considerable resistance to oxidation at high temperatures, their resistance increasing with their silicon content up to 950° C. whilst their tendency to growth decreases with decreasing carbon content.

Heat Stabilization Test. This test is sometimes included in designers' specifications for turbine rotor forgings operating at high steam temperatures, particularly for forgings of the gashed type, as these are more liable to distortion. The test consists of mounting the rotor, which has been accurately machined, in suitable bearings so that it may be rotated inside a furnace whilst being heated up slowly to a temperature somewhat above the estimated service temperature of the turbine. If the rotor is not free from internal stress, or if it has non-uniform thermal expansion properties, distortion will occur during this heating and rotating process so that the rotor runs eccentrically. The eccentricity of the rotor body is read at frequent intervals by means of dial gauges throughout the heating and cooling. (M. 125.)

Heat Time. In *multiple impulse welding* or *seam welding*, the time that the current flows during any one impulse. (A. 37.)

Heat Tinting. A method depending upon differential oxidation which involves heating a *metallographic* specimen, with a suitably polished surface, in air, for the purpose of developing the micro-

structure by oxidizing or otherwise affecting the different constituents.

Heat Transmission Coefficient. Any one of a number of coefficients used in the calculation of heat transmission by conduction, convection, and radiation, through various materials and structures. (See THERMAL CONDUCTANCE, THERMAL CONDUCTIVITY, THERMAL RESISTANCE, THERMAL RESISTIVITY, THERMAL TRANSMITTANCE, etc.)

Heat Treatable Alloy. An alloy whose properties can be modified by heat treatment.

Heat Treating Film. A thin oxide coating or film formed on the surface of metals during thermal treatments. (A. 27.)

Heat Treatment. A process in which steel in the solid state is taken through one or more temperature cycles for the purpose of obtaining certain desired properties. Heating for the sole purpose of hot working is excluded from the meaning of this definition. (See Plate VIII.)

Heat Waste. (See FIRE WASTE.)

Heath, Josiah Marshal. An English steelmaker who appears to have been the first to appreciate fully the possibilities of manganese additions in the manufacture of crucible steels for the purpose of converting inferior grades of blister steels into grades of higher quality (1839).

Heating Curve. (See TRANSFORMATION RANGE.)

Heating Gate. The opening in a *thermit mould* through which the parts to be welded are preheated. (A. 37.)

Heavy Alloy. (See G.E.C. HEAVY ALLOY.)

Heavy Hydrogen. *Deuterium* is an isotope of hydrogen having an *atomic weight* of 2, whilst *tritium* has an atomic weight of 3

Heavy Iron. A defect in the spangle of galvanized sheet caused by an excess of iron in the galvanizing bath.

Heavy Water. Deuterium oxide, D_2O. Its chemical properties are the same as those of normal (light water), but it differs in physical properties, e.g. it is about 10% denser; melting point 3·80° C.; boiling point 101·42° C. Its concentration in ordinary fresh water is about 1:6000, which value may be increased by *electrolysis.*

Heddernheim Kupferwerke Casting-On Process. A *composite casting* process, in which the coating metal is cast on to a steel backing which has previously been heated to a high temperature, and the composite casting is then immediately, i.e. without being removed from the mould or die, subjected to heat treatment, commencing at the temperature which the casting has attained in the mould. In a modification of the process, the non-ferrous alloy is melted by heating with the steel backing and the mould. When molten, the coating alloy flows through a suitable channel into the mould in which it is then held at the same temperature for some time. (S. 31.)

Heddernheim Kupferwerke Immersion Process. A *composite casting* method in which steel bushings to be coated are arranged as ladles and then immersed in a molten salt or borax bath. The molten salt fills the container formed by the steel bushing assembled in a sheet metal holder, the assembly being immediately afterwards plunged into a bath of molten leaded bronze. The molten bronze displaces the molten salt and bonds with the steel backing. In a simplified form, this process can be operated as a through-immersion process, using a layer of molten salt floating on the surface of the leaded bronze bath, the molten salt filling the steel bushing on immersion and then being displaced on deeper immersion into the molten metal. (S. 31.)

Heel. In a twist drill, the edge formed by the intersection of the flute surface and the relief.

Heliarc Welding. A method of welding employed in the U.S.A. in which the electrode, arc and fused metal are surrounded by helium, an inert gas, which protects the weld zone from atmospheric contamination. A water-cooled electrode holder conducts the current to the electrode, which is surrounded by a shielding cup ensuring a concentration of the inert gas in the welded zone. This type of welding is characterized by speed, high quality of the weld, together with advantages from the elimination of flux and the smoothness of deposit. It can be used with ferrous as well as the more common non-ferrous metals. (S. 150.)

Helium. *Atomic weight* 4·03. A colourless inert gas. In the U.S.A where it occurs as a natural gas, it is used as a protective gas in *heliarc welding,* but in the U.K. its use is more restricted, e.g. for low temperature research. It exists in the air to the extent of 0·0005% at sea level. It is the product of the disintegration of a number of radioactive materials. It occurs in various natural gases and in spring water, and is occluded in a large number of minerals from which it can be extracted by crushing the mineral and heating under reduced pressure.

Heli-Welding. (See HELIARC WELDING.)

Helve. The handle of an axe.

Helve Hammer. A form of a mechanically driven trip hammer, formerly used in forging and tool making.

Hemihedral Crystal. A crystal in which are found only alternate planes of the fundamental crystal form. Such crystals thus lack symmetrically opposite faces and have different properties in different directions.

Hemimorphic Crystal. A crystal whose axes of symmetry differ at opposite faces.

Henry. The practical unit of self or mutual *inductance*. (See INDUCTANCE, SELF, and INDUCTANCE, MUTUAL.) Inductance is commonly expressed in millihenries, the millihenry being one thousandth of a *henry*. (A. 28.)

Henry's Law. The weight of a slightly soluble gas that dissolves in a definite weight of a liquid at a given temperature is very nearly directly proportional to the partial pressure of that gas. This holds for gases which do not unite chemically with the solvent.

Heptavalent. Having a *valency* of five.

Her Majesty's Stationery Office. (See STATIONERY OFFICE.)

Herbert Cloudburst Hardness Testing Machines. (See CLOUDBURST HARDNESS TESTING MACHINES.)

Herbert Continuous Hardness Test. A test which produces, automatically, a permanent record of the hardness changes occurring during ageing. The basis of the test is a scratch or groove, rolled by a rotating ball in a slowly traversing specimen. The test, which is shown to be susceptible to changes of hardness due to work-hardening and age-hardening, is used to investigate periodic fluctuations of hardness following magnetic and thermal disturbances. The periodic fluctuations are attributed to electromagnetic pulsations in the atomic structure of the metal. (H. 44.)

Herbert Pendulum Hardness Tester. (*Time Work Hardening Tester.*) This instrument consists of a weight of 4 kgm. resting on a steel ball of 1 mm. diam., or on a ball-shaped diamond and constituting a compound pendulum 0·1 mm. in length. In operation, the pendulum is rested on the specimen and the ball makes an indentation, the size of which depends upon the hardness of the specimen, and when the pendulum is oscillated through a small arc, the time of swing, taken with a stop watch, gives a measure of hardness. The hardness number adopted is the time taken for ten single swings. On hardened steels the diamond and steel ball *time hardness numbers*, multiplied by 13·5 and by 10, respectively, give the Brinell numbers, approximately. For a modification of this test, known as the *Scale test*, the instrument is tilted, until the bubble of the spirit level reaches the one end, at 0, and is then placed on a level surface of the substance. When released, it will swing out to a definite position, which is read off on a scale. This is a function of the deformation work done by the ball on the specimen, and is said to measure its work hardening capacity. (J. 21.)

Herbert's Duplex Sand Mixer. A machine used in the foundry for the preparation of sand. The sand is thrown into a *hopper* and falls between circular discs rotating rapidly in opposite directions. The sand, thrown out by centrifugal force, passes between moving pegs, and is broken up, thoroughly aerated and mixed.

Heredity. The term applied to the alleged tendency for the structure and properties of the pig iron to be repeated in the casting. (G. 18.)

Herman Process. A hot-dip process for galvanizing wire. In this process there is a small auxiliary zinc pot at the exit end of the main pot. The wires are drawn up through a slot-shaped nozzle, 10 in. high, through which molten zinc is circulated. Above the nozzle there is a chamber of about 6 cu. ft. which is kept full of natural gas. The wires pass up through the gas and are cooled in a stream of water directed across them. (H. 86.)

Hermansen Furnace. A gas-fired recuperative annealing furnace. The recuperators consist of specially manufactured hollow firebricks, which are made with ribs on the outside, top and bottom. These bricks are so built together as to form a number of parallel square flues through which the waste gases pass in a downward direction on leaving the furnace, and transverse flues through which the secondary air passes in very thin layers These transverse flues are joined together on either side of the gas flues by longitudinal flues. The secondary air, regulated by slides, is introduced into the lowest of the heating flues, and runs alternatively left and right through the horizontal transverse flues in an upward direction, finally reaching the combustion chamber through the special flues. (F. 30.)

Heroult Electric Arc Furnace. A *direct arc furnace* having three electrodes, one phase of a three-phase current being brought to each electrode. In plan, the electrodes form an equilateral triangle. The current travels from electrode to electrode through the medium of arcs made with the bath.

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Plate IV.—Tapping electric arc furnace (Heroult type).

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The electrodes used in this furnace may be either graphite or amorphous carbon. Graphite electrodes have approximately four times the conductivity of amorphous carbon and thus an electrode only half the size will carry the same current. All electric steel melting furnaces are made to tilt. In a top-charged arc melting furnace, the whole charge can be placed at one time by means of a drop bottom basket. In general, for the production of steel ingots, the basis of the hearth is of magnesite brick, and such furnaces are termed basic units, whilst most of those used for the production of castings have linings of acid materials, such as silica brick, silica sand or ganister, and are thus acid units. (See Plate IV and Fig. 5.) (H. 6.)

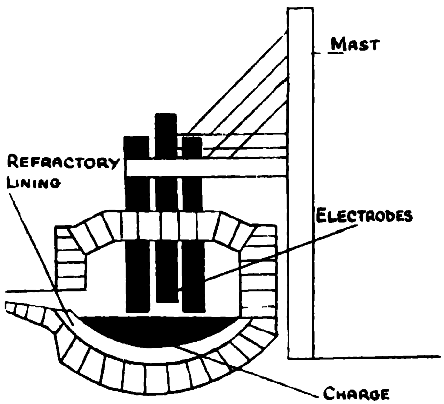

Fig. 5.—Diagrammatic cross section of typical electric arc furnace of the Heroult type.

Heroult, P. L. T. (1863–1914.) A French metallurgist.

Heroult Process. An electrolytic process for the extraction of aluminium from bauxite.

Herreshof Furnace. (See BRASSERT PROCESS.)

Herty Method for the Determination of Inclusions. The method employs a micrometer ocular at a magnification of 250 diameters. Thin strips of a given area of the section through the casting are surveyed from the centre to the outer edge for inclusions, which are segregated into various sizes according to their diameter. The weight percentage of non-metallic matter is then calculated. (H. 47.)

Hess' Law of Constant Heat Summation. The amount of heat generated by a chemical reaction is the same whether reaction takes place in one step or in several steps, since all chemical reactions which start with the same original substances and end with the same final substances liberate the same amounts of heat, irrespective of the process by which the final state is reached.

Heterogeneous Structure. A metallic structure with more than one phase.

Hewettite. ($CaO.3V_2O_5.9H_2O$.) A hydrated vanadate of calcium found in Peru.

Hexagonal. Concerning crystals, having parallel 6-fold rotation axes of symmetry or a single set of parallel 3-fold rotation axes of symmetry with planes of symmetry perpendicular thereto, and with or without other symmetry elements. The typical hexagonal crystal has two equal axes, b = a, inclined at an angle of 120 degrees and a third axis, c, perpendicular to their plane. (A. 27.)

Hexagonal, Close Packed. (See CLOSE PACKED HEXAGONAL.)

Hexagons. Hot rolled steel bars hexagonal in cross-section.

Hexavalent. Having a *valency* of six.

Heyn's Reagent. An etching reagent containing 10% copper ammonium chloride in water.

Hf. Chemical symbol for *hafnium*.

HF. Chemical formula for hydrofluoric acid.

H Factor. A factor sometimes used in the U.S.A. to express the severity of a quench.

H.F. Furnace. (See HIGH FREQUENCY INDUCTION FURNACE.)

Hg. Chemical symbol for *mercury*. From the Latin *hydragyrum*.

HI. Chemical formula for hydriodic acid.

Hicks' Hydrometer. An instrument consisting of a series of coloured glass beads of different densities contained in a glass tube. It is used for testing the specific gravity of electrolytes.

Hidden-Arc Welding. A method of *automatic welding* developed for joining the seams of bomb boxes made of 13-gauge steel sheet. The edges of the sheet are held in a jig which also forms a V groove into which the powdered flux is fed at the side of a guide wheel. The electrode wire is fed from a coil into the flux. Since the arc and molten metal are completely blanketed by flux, the weld metal is protected from contact with air and high quality welds are assured. (C. 1.)

Hiddenite. (See SPODUMENE.)

Hidensity Arc Welding. (*High Density Welding.*) The process uses either a $\frac{3}{32}$ in. or a $\frac{5}{64}$ in. diam. *electrode* wire with welding currents of up to 600 *amperes*. These high densities create a deeply penetrating arc which in turn allows the use of high welding speeds. (W. 29.)

Hidraw Process. A deep drawing process which employs a combination of a rubber pad and an opposing hydraulic cushion, and can also be used for *Guerin* and die-quenching operations. Among the advantages claimed for the technique is the high quality of surface finish on the parts produced. The rubber acts as a fluid medium and, since there is no *ironing* of the work material, parts are produced with a uniform wall-thickness and a minimum of stretching. Some components which, due to their shape, have proved difficult to form by the methods employed hitherto, can be produced complete in one operation from the blank, by virtue of the fluid action of the rubber, which ensures that virtually no metal is unsupported during the operation. (M. 50.)

Hi-Electro Installation. (See BUDD INDUCTION HARDENING.)

H.I. Furnace. A type of *open hearth furnace*, named after the Japanese engineers Hiraoka and Icheda, has been designed to facilitate charging and to prolong the life of the roof. The furnace is characterized by the fact that it has a suspended roof and an all door front. (I. 1.)

High Alumina Refractories. Refractories containing over 40% of alumina.

High Bloomery. (See WOLF'S OVEN.)

High Density Welding. (See HIDENSITY ARC WELDING.)

High-Duty Alloy Cast Irons. The term high-duty alloy implies some outstanding property such as high mechanical strength, hardness, resistance to heat, wear or corrosion, special electrical or magnetic properties, etc., conferred by the addition of various elements which are not ordinarily present in significant quantity. Included in the category are irons in which elements normally present are in unusual amounts, resulting in special properties, as in the case of the high silicon or high manganese irons. (B. 38.)

High Frequency Induction Furnace. (*Coreless Induction Furnace.*) Essentially an air transformer in which the primary is a water-cooled spiral of copper tubing, and the secondary the metal being melted. When high frequency current is applied to the terminals of the helix of the copper tubing, all the space inside the coil is subjected to a rapidly alternating electromagnetic field. Any electric conductor inside the coil (in practice the furnace charge), has currents induced in it, causing rapid and efficient heating and thorough stirring of the charge. These furnaces are generally of small capacity, up to about 5 tons, and can be quickly charged and teemed. There is little oxidation and no pick up of impurities such as sulphur and therefore this type of furnace is increasingly used for the production of special alloy steels. (See Fig. 6 and Plate V.)

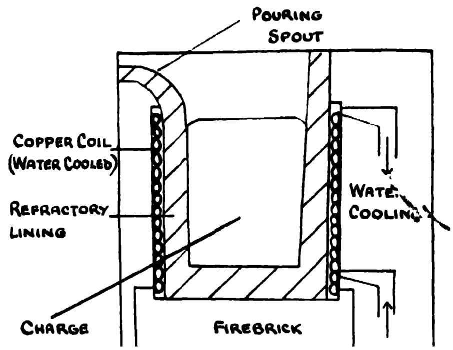

Fig. 6.—Diagrammatic cross section of a high frequency induction furnace.

High Frequency Ionization Apparatus. An apparatus which permits the welding of non-ferrous metals and austenitic steels with the conventional A. C. transformer equipment, by the addition of an ionizer.

High Frequency Notch Bend Test. The method is based on the production, by high frequency induction heating within a specimen, of the same metallurgical change as occurs within the heat-affected zones of a multipass arc weld produced in companion materials. Notched specimens $\frac{3}{8}$ in. by $1\frac{1}{2}$ in. by 8 in. are employed whose stress concentration value equals that obtaining at the toe of a fillet of a tee-bend specimen. A single-turn coil restricts the heating effect to a $\frac{1}{2}$ in. width in the middle of the 8 in. long specimen. The temperature is raised from 20° to 1175° C. in 49 seconds. The notch sensitivity of the base metal is determined by deforming a notched test bar in the adjustable bending jig. The sensitivity is expressed by the radius of the smallest plunger under which the base metal deforms, with the notched side in tension, without developing defects in excess of $\frac{1}{8}$ in. in any direction, and the treated centre portion of the sample should deform similarly with the same size plunger. (R. 38.)

High Frequency Treatment. (See INDUCTION HARDENING.)

High-Jet Method. A lubricating technique which consists of directing high-speed streams of oil to the underside of the cutting edge of the tool. Part of the oil is forced between the work-

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Plate V.—Teeming experimental high frequency furnace.

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piece and the cutting edge and is caught between the chip and the tool. The liquid, near boiling point at the cutting edge, vaporizes and passes up through the channels caused by the difference in roughness between the cut face and the tool edge. It then condenses on the chip and tool shank. It is claimed that this method of lubrication eliminates tool build-up and reduces nose-radius wear whilst surface finish is greatly improved.

High Sintering. Synonymous with advanced sintering at high temperatures, usually the final sintering close to the melting point of the material. (G. 30.)

High Speed Steel. A high-alloy steel, capable of intense hardening, used for metal-cutting tools. It retains its hardness at a low red heat, and hence the tools can be used in lathes, etc., operated at high speeds. It usually contains 12% to 22% tungsten, up to 5% chromium, up to 1% carbon, and varying amounts of other elements (vanadium, molybdenum, cobalt, etc.). Alternatively, the tungsten may be replaced wholly or in part by half its weight of molybdenum.

High Strength Steel. A term applied in the U.S.A. to low alloy structural steels forming a specific class in which enhanced mechanical properties are obtained in the rolled condition. It is claimed that the addition of moderate proportions of alloying elements other than carbon, not only enhances the mechanical properties but gives increased resistance to atmospheric corrosion.

High Temperature Oxidation. (*a*) Preferential attack on certain alloy constituents in light metal alloys during solution heat treatment. (See INTERNAL OXIDATION.) (*b*) Oxidation of ferrous alloys at temperatures below that at which the rate of scaling becomes rapid.

High Temperature Steels. A name sometimes given to *heat-resistant steels*.

High Temperature Test. (See CREEP and SHORT TIME TENSILE TEST.)

Hindered Contraction. A restriction of the free contraction of a metal or an alloy. It is caused mainly by the design of the casting and by the materials and methods used in moulding and coring.

Hi-Speed-It. A powder compound that is claimed to confer upon low carbon steel the cutting properties of tool steel. (C. 50.)

Hjelm, P. J. (1746–1813.) A Swedish chemist who isolated molybdenum in 1782.

HL. (See LUDWIG HARDNESS.)

HNO_2. Chemical formula for nitrous acid.

HNO_3. Chemical formula for nitric acid.

Ho. Chemical symbol for *holmium*.

H_2O. Water.

H_2O_2. Hydrogen peroxide.

HOAG Desiliconization. (See p. 473).

Hob. (*a*) A hardened steel tool of a desired shape used to form a cavity in the *hobbing* operation. (*b*) A spiral tool for cutting gear teeth in a *hobbing* machine.

Hobbing. (*Hubbing.*) (*a*) A process of forming cavities in soft steel blanks by forcing a *hob* or pattern into the blank, so that it accepts the contour of the hob. In hobbing a simple cavity, of symmetrical shape, on the bottom surface of which no raised lettering or other design is required, the tool is merely pressed straight into the blank. The hob, which has been thinly coated with copper by means of a copper sulphate solution, to provide a lubricating effect, is placed centrally on the blank surface and pressure is applied so that the metal of the blank can flow out from beneath and up the sides of the hob without restraint. (D. 25.) (*b*) Cutting the threads of worm wheels, dies or chasers with a hob or master tap in a lathe. Also cutting the teeth of gears with hobs in machines specially designed for this work. The distinguishing feature which separates the hobbing machine from other gear cutting machines is that the gear is produced by the simultaneous rotation of the hob and the gear blank being cut.

Hoerde. (See MASSENEZ PROCESS.)

Hoesch Process. A method of working the open hearth furnace in the *duplex process* so as to reduce as much as possible the amount of manganese lost in the slag in the production of manganese steels. The method includes the use of runners, lined with a tar-dolomite mixture instead of sand, when transferring the open hearth iron from the ladle to the steel furnace, working the furnace with a high carbon concentration and taking care not to produce a highly basic slag, and the adoption of a special method of teeming when tapping the finished steel. This consists of holding the ladle in an almost horizontal position against the runner from the *tap-hole* and gradually bringing the ladle, to the vertical position as it fills. This prevents the metal from falling vertically into the ladle, and there is, therefore, no turbulence. The amount of manganese lost is reduced by 25% to 35% by adopting this pouring technique, and results in a saving of 50% in the ferro manganese additions. (B. 13.)

Hofors Slag Inclusion Count. (See S.K.F. INCLUSION SCALE.)

Höganäs Process. (*Siurin Process.*) A

method for the production of *sponge iron* which consists of charging fireclay pots, about 5 ft. high, with flat briquettes of a concentrate containing 71·5% of iron ore interspersed with layers of carbon, prepared by mixing coal with coke breeze; the pots are charged in batches in a long pit furnace where they are heated to about 1200° C., the total time in the furnace being about 12 days. The pots are emptied by manual labour and put on a conveyor which takes them to tumbling machines where the ash and dirt are removed. (E. 9.)

Hoggatt's Penetrometer. An instrument for the determination of hardness and in particular of gypsum wall panels. It consists of a needle which is retractable into a housing, being held normally in a protracted or extended position by means of a long coiled spring of such strength as to apply a yielding pressure of ten pounds on the needle. The device comprises also gauge means for indicating visually the amount of penetration of the needle into the article being tested, together with means for adjusting the degree of compression of the spring for bringing the device to a predetermined standard of operation. (H. 64a.)

Hogging. The removal of risers, etc., from castings by *flame cutting*.

Hold Down. The tool that exerts pressure normal to a sheet blank during deep drawing, in order to prevent wrinkling and to cause uniform circumferential compression while the large circumference of the blank is reduced to that of the shell. (A. 27.)

Holdcroft Thermoscope Bars. Temperature indicators which consist of a series of small bars placed horizontally on a refractory stand. On heating, some bars are bent to varying degrees, others are unaffected. The temperature is indicated by the bar that is just beginning to sag. The bars are numbered 1 to 40; the temperature range being 600° to 1550° C. (B. 106.)

Holding Furnace. A small furnace for maintaining molten metal, from a larger melting furnace, at the desired casting temperature.

Holding Time. (*a*) The time allowed in the reheating or heat treatment of a steel for the heat to penetrate into the mass and for the steel to attain a uniform temperature throughout its section. Naturally the holding time increases with the diameter of the piece under treatment. (*b*) In *spot* and *projection welding* the time during which force is applied at the point of welding after the last impulse of current ceases to flow. (*c*) In *seam, flash* and *upset welding*, the time during which force is applied to the work after current ceases to flow. (A. 37.)

Hole. (*a*) In wire drawing, the hole in the *die*. (*b*) The term is also used in wire drawing to denote the *draft*, e.g. the wire may be one or two holed.

Holiday. A flaw in a paint coating permitting contact of the electrolyte with the bare metal.

Hollow. The name given in the cold drawing mill to the hot finished tube, which is the raw material of the cold drawing process.

Hollow Drawing. (*Over Drawing.*) An effect in which too severe a degree of cold working, as may be due to insufficient intermediate annealing, so reduces the ductility of the material as to cause local failure, shown by the development of transverse internal fissures. There is often no external evidence of hollow drawing.

Hollow-Electrode Furnace. (See WILES' PROCESS.)

Hollow Forging. A method of producing hollow bodies, e.g. steel tubes or pressure vessels, in which a comparatively small hole, *trepanned* in a solid forging, is expanded on a *mandrel* under a forging press, or on a *becking bar*.

Hollows. A term applied in moulding to curved surfaces, connecting two flat surfaces which would otherwise meet at an angle. Such curves facilitate the withdrawal of the *pattern* and strengthen the casting.

Holmberg System. A method of sintering iron ore. Sintering is carried out in a series of pans, 11 ft. 6 in. square, with robust chromium vanadium steel grate bars, which have a life of 5 to 6 years. Advantages include low fuel consumption and absence of moving parts in the sintering zones. (R. 33.)

Holmium. (*Ho.*) A member of the erbium family or *rare earth metals*. *Atomic weight* 164·94. The free element has not been isolated.

Holocrystalline. Composed entirely of crystals without the presence of any amorphous material.

Holohedral. A crystal having perfect symmetry.

Holtzmann Mechanical Generator. A device for the production of ultrasonic waves. (H. 68.)

Homberg's Phosphorus. A phosphorescent material produced by heating together one part of ammonium chloride with two parts quick lime.

Homogeneous. Usually defined as having identical characteristics throughout. However, physical homogeneity may require only an identity of lattice type throughout, while chemical homogeneity

requires uniform distribution of alloying elements. (A. 27.)

Homogeneous Carburizing. This process consists of a complete carburization of articles of small cross-section, such as wire, stampings, and so on, of low carbon steel. The difference between this and normal surface carburization lies in the carbon potential of the furnace atmosphere which is so adjusted that the carbon content cannot build up, even at the surface, beyond that required throughout the work. In the control of this atmosphere which is made up of carbon monoxide, hydrogen, and nitrogen, and also contains water vapour, the dew-point is found to be a useful index of the carburizing power and the temperature required. (C. 61.)

Homogeneous Deformation. An effect resulting from normal cold working operations, such as rolling, in which the individual crystals are each deformed in direct proportion to the amount of deformation on the whole mass.

Homogeneous Welding. The welding of two like metals.

Homogenizing. A process of heat treatment at high temperature intended to eliminate or decrease chemical segregation by diffusion. (A. 27.)

Homologous Pair. In *spectrographic analysis*, a homologous pair consists of an analysis line and an internal standard line, such that the ratio of the intensities of the radiations producing the lines does not change with variations in the conditions of excitation.

Homomorphous. A term applied to substances which crystallize in a similar form but are chemically distinct.

Homopolar Crystals. Crystals where neighbouring atoms share electrons; for instance, diamond, where the four outer (valence) electrons of each carbon atom are shared with its four nearest neighbours, thus completing an outer shell of eight electrons per atom. (A. 27.)

Honda-Sato Pendulum. A dynamic hardness testing instrument of Japanese design which employs a 10 mm. ball indenter and variable striking energies.

Honda Steel. (See MAGNET STEELS.)

Hone. (See HONING.)

Honing. A method of removing imperfections of surface left by previous operations. The *hone* consists of bonded abrasive sticks which are applied to a surface under controlled pressure, and with a combination of rotary and reciprocating motions. Its function is the production of geometrically round and straight surfaces with a minimum of heat or disturbance of the crystalline structure of the material, and the production of accurate size. Honing also produces a type of surface finish unobtainable by any other method, and to any desired degree of smoothness. (M. 57.)

Hook. A short bend or curvature in a bar, caused either by improperly adjusted delivery guides or by an obstruction which may halt momentarily the forward motion of the bar from one roll stand to another.

Hooke, Robert, F.R.S. (1635–1703.) The author of *Micrographia* published in 1665. He made many very notable contributions to science. (A. 42.)

Hooker Process. An impact extrusion process in which a shell is first formed by one or two piercing operations or by drawing (cupping) and coining the bottom to the desired thickness. This shell is then extruded into a part with a thinner wall, and extracted from the die by punch trimming.

Hooker Virgo Salt Descaling. In this method, the work to be descaled is immersed in a bath containing the patented Virgo salt. This is a mixture of salts which has the property of chemically converting scale and other impurities on the metal surfaces. The molten salt dip is followed by a water quench and then by a short acid treatment for the removal of the converted scale. In the treatment of stainless steels, a subsequent brightening and passivating dip is sometimes employed. The scale is completely removed in a fraction of the time usually required for acid pickling and moreover, the process is such that the salt reacts only with the oxide. Metal losses are therefore negligible. The short acid dip which follows the water quench removes the converted scale on the work.

Hooke's Law. This law states that "within the limits of *elasticity* the *strain* is proportional to the *stress* producing it". The value of the stress at which a material ceases to obey Hooke's Law is known as the *limit of proportionality*.

Hoop Iron. Thin strip-iron used for securing barrels, and also for various purposes in the building trade, e.g. as reinforcement in brick walls.

Hoope's Process. A process for the refining of aluminium electrolytically to a purity of 99·99%.

Hopkin's Process. (See PLURAMELT PROCESS.)

Hopkinson's Fatigue Testing Machine. This machine was devised for applying alternating direct stresses and consists of an electro magnet, excited by alternating current in the winding, which exerts a periodically varying pull along the axis of the test piece fixed rigidly

to the base of the machine and supporting a heavy mass of iron carrying a laminated armature piece. The frequency is twice that of the exciting current, and the test piece acts as a stiff spring, adjustment being such that the natural period of oscillation of this spring coincides with the period of magnetic pull. The range of stress in the specimen is adjusted by changing the *e.m.f.* applied to the coils. The machine was designed to apply 7000 alternations of stress per minute. (G. 36.)

Horn. In *resistance welding*, a beam or arm extending from the frame of a welding machine, which transmits the electrode force and usually conducts the welding current. (A. 37.)

Horn Gate. A *gate* made in the shape of an arc of a circle and tapered gradually from one end, adjacent to the *casting*, to the other end which joins the *downgate*.

Horn Mercury. (See CALOMEL.)

Horn Spacing. In a *resistance welding* machine, the unobstructed work clearance between *horns* or *platens* at right angles to the throat depth. This distance is measured with the horns parallel and horizontal at the end of the downstroke.

Horns. Projections on the ends of rolled sheet or strip caused by uneven pressure during rolling, due to the rolls being worn in the centre, or of incorrect camber.

Hornsey Process. A method for the low temperature reduction of iron ore by means of a series of rotary kilns. The kilns are each about 5 ft. in diam. and 30 ft. in length. The first is used for preheating, the second for reduction, and the third for cooling the product. Pulverized coal is used which makes it possible readily to control the combustion and to maintain constant temperature. At no point in the process does the temperature rise above 1050° C. The iron product is separated from the *gangue* by passing over magnetic separators. The product differs physically from that of the blast furnace, in that it is in granular form instead of being in the shape of pigs. It also differs chemically in that the iron reclaimed is essentially pure, resembling wrought iron, and is mixed mechanically with varying percentages of the other ingredients of the ore instead of being chemically combined with them. (I. 84.)

Horophile. Benedicks and Lofquist have stated that in solid solutions the concentration of a dissolved element must be generally higher, or lower, in the surface layer and designated them as *horophile* or *horophole* substances respectively. The presence of horophile substance is assumed to exert a stabilizing action on the boundary surface. (N. 14.)

Horophole. (See HOROPHILE.)

Horsefall Process. A method used in the production of piano wire in which the wire was cold drawn until it was nearly down to the required diameter. It was then heated to redness and quenched in oil or water, tempered in molten lead, after which the drawing was completed.

Horsepower. (*h.p.*) The British unit of power which may be defined as the work done in a given time, and is the performance of 33,000 foot-pounds of work per minute.

Horse Shoe Quality. A grade of wrought iron specially manufactured for horse shoes.

Horton Multisphere. A pressure vessel made up of two or more spherical sections with one or more internal diaphragms to take the component of the stresses in the shell where the adjoining sections come together. The shell of the vessel consists of a series of spherical segments. Each segment intersects the adjoining segment in a common plane, and a diaphragm consisting of a flat plate is placed in each plane thus formed. (A. 52.)

Hot Bed. A large enclosed area containing closely spaced rolls or rails for holding hot, partially rolled metal. (A. 27.)

Hot Bend Test. A test applied to wrought iron chains in which each half link tested, heated to a bright red (930° to 980° C.) shall be capable of being bent by pressure or by a succession of light blows, without hammering direct on the bend until the edges of the link are in tight contact, without sign of fracture on the outside of the bent portion. (B. 100.)

Hot Blast Cupola. (See CUPOLA.)

Hot Blast Stoves. Tall cylindrical refractory lined regenerative chambers filled with a checker work of refractory brick. They may be up to 125 ft. in height, and are used for preheating the air for the blast furnace. Each blast furnace has at least two stoves, in one of which the refractory checker work is being heated by the burning gases coming from the top of the blast furnace, whilst the other is giving up the heat so derived to the incoming air blast.

Hot Cracks. Intercrystalline tears, the surfaces of which are blued by oxidation, which occur in mild steel welds at an elevated temperature. (R. 37.)

Hot Deformation. (*a*) (See HOT FORGING and HOT ROLLING). (*b*) The change of form of a specimen of moulding sand

during the determination of its *hot strength*.

Hot Dipping. (See HOT GALVANIZING.)

Hot Drawing Wire. A process suitable for drawing high-carbon and high-alloy steel wire, in which the material, after hot rolling to rod, is coiled and fully annealed, and then passed through a gas-heated lead bath heated to 510° C. before it is drawn through the preheated tungsten carbide die. The actual drawing temperature is about 330° C. The drawing does not harden the wire, and a superior product is claimed. (S. 19.)

Hot Electrode. An electrode with a special coating, developed as a means of applying intense local heat to a steel surface. Practically all the metal of the electrode is oxidized and the coating forms a semi-liquid slag on the surface being treated. In multi-run welds on thick plates the structure of the last run remains coarse so that the whole work, e.g. a boiler, has to be normalized. The deposition of a slag coating by the heating electrode on top of the last run not only causes the latter to solidify with a fine crystalline structure but also very greatly reduces the hardness of the heat-affected zone, and in some cases subsequent heat treatment of the whole vessel is not necessary. (S. 24.)

Hot Extrusion. (See EXTRUSION.)

Hot Finishing Mill. A *rolling mill* which may consist of either a single stand of rolls on which all rolling operations from bar to finished sheet are carried out or of two stands, one for the roughing down of the bar, and the other for finishing the hot rolling of the sheet.

Hot Forging. (See FORGING.)

Hot Forming. Working operations, such as bending and drawing sheet and plate, forging, pressing, and heading, performed on heated metal.

Hot Galvanizing. A process in which mild steel articles are pickled in hydrochloric acid, or sometimes in sulphuric acid, washed, dipped into molten flux, which is allowed to dry on, and then passed through a bath of zinc at a temperature above its melting point (420° C.) and covered with a suitable flux, usually ammonium chloride. Sheets are usually quenched in water after leaving the zinc bath and then passed over a drying fire.

Hot Impact Tests. A standard impact machine is employed, the specimens being heated in a suitable medium prior to transfer to the impact machine.

Hot Ingots. (*a*) Ingots which must not be allowed to cool between stripping and hot working owing to the fact that their composition renders them liable to cracking. (*b*) Ingots which are cast and worked without reheating for purposes of heat economy.

Hot Junction. (See THERMOCOUPLE.)

Hot Lip-Runner Method. (See CONNOR RUNNER.)

Hot Machining. Metal cutting at elevated temperatures using arc- and oxy-acetylene heating methods, which has resulted in improved machinability, and longer tool life. (A. 49.)

Hot Metal. Pig iron in the molten condition.

Hot Metal Mixer. (See MIXER.)

Hot Metal Process. A steelmaking process in which the charge consists wholly or partly of molten metal from the *blast furnace*, *mixer*, or *cupola*. (See BASIC STEEL.)

Hot Permeability. The property of the sand in a sand mould to allow gases to escape at temperatures above room temperature.

Hot Piercing. A hot rolling operation in the production of seamless steel tubes, the billet or bar being pierced centrally and worked on a mandrel into the form of the tube.

Hot Pressing. (*a*) The simultaneous pressing and sintering of carbide tools. The powder is placed in a closed mould, usually of graphite. The mould and its contents are heated to the sintering temperature while pressure is applied in one direction to overcome the forces that cause shrinkage in the two other directions. Moulds are usually electrically heated, and pressures commonly used are from 400 to 2500 lb. (*b*) The shaping under a press of articles from plate or sheet at elevated temperatures.

Hot Pressure Welding. (See FORGE WELDING.)

Hot Quenching. A process of cooling in a medium, the temperature of which is substantially higher than atmospheric.

Hot Rod. A term used in America for a welding electrode of a fairly fluid type which has to be used with a high current and in the horizontal position.

Hot Rolled Bar. The term applied to bars which have been hot rolled from *billets* and then air cooled or allowed to cool normally.

Hot Rolled Strip. The product from the hot rolling of a slab, billet or sheet bar either in the form of coil or flat lengths.

Hot Rolling. The operation of compressing and lengthening a piece of metal between two rolls rotating in opposite directions, the flow of metal being continuous and almost entirely in the longitudinal direction.

Hot Sawing. Cutting steel to length immediately after *hot rolling* by means of a circular saw.

Hot Short. Brittleness in metal at certain ranges above normal room temperature. It is manifested by loss in ductility and a liability to crack under stress at the particular temperature.

Hot Spot Machining. This method differs from *hot machining* in that only a spot ahead of the tool is heated and this spot is machined away as fast as it is heated. (T. 46.)

Hot Sprueing. The removal of castings from *gates* before the metal has completely solidified. This operation is necessary on light section or intricate castings which might be cracked if *cold sprued*. (A. 26.)

Hot Stamping. Shaping or forming heated metal in a press or hammer.

Hot Strength. The term as applied to moulding sand, relates to the *tenacity* (*compressive, shear, tensile* or *transverse*) of a sand mixture, determined at any temperature above room temperature. (A. 26.)

Hot Stretching. A process in which wire is drawn without the use of *dies*.

Hot Tearing. The formation of cracks (*hot tears*) in ingots or castings during cooling in the mould, i.e. the portions which have been last to solidify, have ruptured during solidification as a result of stresses set up in the ingot or casting as it contracts on cooling.

Hot Tears. (See HOT TEARING.)

Hot Tinning. A hot dipping process in which pickled steel sheets, cut to size, are passed through molten tin, contained in a cast iron or steel vessel, known as the *tin pot*, which may be heated by coal, oil or gas or in more modern plants, by thermostatically controlled electric immersion heaters.

Hot Top. (See FEEDER HEAD.)

Hot Trim. The removal of the *flash* on a forging while still hot by means of a trimming press.

Hot Twist Test. A test for determining the optimum hot working range of different steels and, in addition, affording an indication of the strength of the steel at elevated temperatures. The test bar is 21 in. long and $\frac{5}{16}$ in. in diam. and is placed in the furnace with both ends protruding, one of which is held in a power-driven chuck and the other attached to the torque arm. After the bar is brought to temperature, it is twisted at a speed of 135 r.p.m. The torque required to twist the bar is measured directly on a platform balance and a counter records the number of revolutions to failure.

Hot Upset Test. (*a*) A test developed for determining the optimum hot working range of different steels. The usual procedure in conducting the test is to prepare specimens $1\frac{1}{2}$ in. long and $\frac{3}{4}$ in. in diam., heat these in pairs to various temperatures in the hot working range and then upset one specimen with a single blow of a forging hammer to a flat disc $\frac{1}{4}$ in. thick and the other to a similar disc $\frac{1}{8}$ in. thick. An excellent correlation has been obtained between the results of such hot upset tests and mill performance in rolling full-size ingots. (*b*) A test involving the hot compacting of a test piece in order to check the presence or absence of surface defects.

Hot Working. The mechanical working by *rolling, forging* or *extruding*, of a metal or alloy at a temperature above its recrystallization point. This temperature varies according to the composition of the alloy material.

Hot Working Steel. Steel which is designed primarily for production of tools and dies which are intended to be used for work with hot metal.

Houghto-Black. A process of forming a black coating on iron and steel. It uses a strong caustic solution which contains oxidizing salts. Concentration of the bath is such as to give a solution which boils at 143° C. This is approximately 10 lb. of the salt to one gallon of water. If the bath is allowed to go to 133° C. or lower or if allowed to go above 148° C. the coating produced will be brown instead of black. (L. 48.)

Hounsfield Balance Impact Machine. This employs two equal masses moving at the same speed in opposite directions. The test piece and knife edge are located exactly at the centre of percussion of the two swinging weights, so that all stresses due to the impact are cancelled out, and there is no reaction on the ball bearings from which the tups are suspended. (A. 62.)

Hounsfield Tensometer. A portable machine for making tensile, hardness and bend tests on small specimens. (A. 60.)

Housing Adjusting Screws. (See ROLLING MILLS.)

Housings. (See ROLLING MILLS.)

Howden Hardness Tester. An indentation hardness testing machine in which either a 136° diamond pyramid or balls of 1, 2 or 5 mm. diam. may be employed. The specimen under test is screwed upwards until it presses against the indenter. The load, which may be varied from 5 to 125 kg., is applied by either of two interchangeable measuring springs connected to a lever which operates the pointer on a dial.

Howe, Henry Marion. (1848–1922.) An American pioneer metallurgist. Professor of Metallurgy at Columbia Uni-

versity and the author of *Metallurgy of Steel* (1888) and of *Iron and Steel and Other Alloys* (1903).

Howell-Howarth Fatigue Testing Machine. In this machine, the specimen acts as a cantilever fastened at one end. It remains stationary during the test. The other end of the specimen is deflected a measured amount by putting a pivoted bearing in a rotating head a definite amount off centre. The specimen is calibrated by dead weights for deflection and thus is its own dynamometer. This type of machine differs from the vibratory type in that as the free end of the cantilever is rotated in the circle, all the longitudinal fibres are subjected to reversed stress. (A. 35.)

Howlite. Hydrated calcium silico-borate. In basic arc furnace practice, Howlite has been added before shut-down periods, to treat the final white falling slag and hearth. It is claimed that this stabilizes the banks and hearth, thereby preventing deterioration during the shut-down period. The Howlite addition (36 lb. to a slag bulk of about 10 cwt., giving about 0·7% of boric oxide in the final slag) is made to the last three or four casts before shut-down. (S. 87.)

h.p. *Horse power.*

H.P.N. Process. A modification of the *basic Bessemer process*, for producing *H.P.N. steels* with a low phosphorus and nitrogen content. The addition of iron ore, about two minutes before the end of the carbon combustion, is found to be very efficient, as it shortens the *blow* and lowers the temperature, thus also lowering the phosphorus content of the steel. (G. 7.)

H.P.N. Steels. German Bessemer steels containing 0·005% to 0·007% nitrogen, and having a low phosphorus content. (E. 24a.)

H_2S. Chemical formula for hydrogen sulphide.

H_2SO_3. Chemical formula for sulphurous acid.

H_2SO_4. Chemical formula for sulphuric acid.

H.T. (*a*) High tension. (*b*) High tensile.

Hub. (*a*) A projection, round or otherwise, usually the centre of a rotary movement. (*b*) A boss which is in the centre of a forging and forms a part of the body of the forging.

Hubbing. (See HOBBING.)

Hubnerite. A tungstate of iron and manganese $(Fe,Mn)WO_4$.

Huegelite. A vanadium ore, hydrated zinc lead vanadate.

Huelva Ore. A Spanish haematite containing arsenic.

Huey Test. (*Boiling Nitric Acid Test.*) A test for corrosion resisting steels in which the specimen is completely immersed for 48 hours in a boiling 65% solution of nitric acid, sufficient to provide at least 125 ml. of solution per square inch of surface area. The specimen is then removed, rinsed, freed of any adherent corrosion products, dried, solvent degreased and weighed. The test is repeated to a total of five 48-hour periods, weight loss being determined and fresh acid provided for each test period. (A. 36.)

Huggenberger Extensometer. An instrument employing a compound lever system magnifying about 1000 times and giving readings to an accuracy of at least 0·00001 over a gauge length of 2 in.

Hughes Supersonic Flaw Detector. (See KELVIN AND HUGHES MK. 5 CRACK DETECTOR.)

Hull Method. A method for X-ray crystal analysis, using a monochromatic (or polychromatic) X-ray beam defined by slits or pinholes, an aggregate of small crystals oriented more or less completely at random and a photographic plate or a photographic film (if a film, bent around a cylinder with its axis perpendicular to the X-ray beam at the crystalline specimen); virtually indistinguishable from the *Debye-Scherrer method*; sometimes called the *powder method*. (A. 27.)

Hultgren Balls. High carbon steel balls, so treated that they may be used as standard penetrators in the *Brinell test*.

Humectant. Any material added to foundry sand to retain moisture. (A. 26.)

Humfrey's Reagent. A modification of *Heyn's reagent*. The steel under examination is first immersed in an 8% to 12% solution of copper ammonium chloride in water for from 10 to 30 minutes and then for a further half-hour in a similar solution, to which has been added 2½% to 5% of hydrochloric acid. The steel is then immersed for a third half-hour in the solution to which a further addition of 15% of hydrochloric acid has been made (with possibly an intermediate period with 7½% to 10%). If necessary, still stronger acid solutions are employed to obtain the required effect. One advantage of this process is that the structure stands out in relief and may be reproduced by contact printing.

Humidify. To increase, by any process, the density of water vapour within a given space.

Humidity. Water vapour within a given space.

Humidity, Absolute. The weight of water vapour per unit volume, pounds per cubic foot or grams per unit centimetre.

Humidity Ratio. (*Specific Humidity.*) In a mixture of water vapour and air, the weight of water vapour per pound of dry air.

Humidity, Relative. The ratio of the actual partial pressure of the water vapour in a space to the saturation pressure of pure water at the same temperature.

Humidity, Specific. (See HUMIDITY RATIO.)

Humphrey Abrasion Testing Machine. A machine for the determination of wear in metals under controlled humidity conditions. (R. 2.)

Humphris Toggle-Action Press. In this type of press, a number of toggle levers distribute the thrust over the whole area of the platen, so that sticking in the guides does not occur. It is thus possible to stamp out a multiplicity of small articles from large sheets, with the further advantage that the scrap produced is in a saleable form. (E. 37.)

Hump Method. A method for determining when the *transformation point* has been reached in material under *heat treatment*, which makes use of the bend or hump shown by a recording *pyrometer*. (A. 58.)

Hunter Reflectometer. An instrument for measuring the reflectivity of a metallic substance. (Z. 4.)

Huntsman, Benjamin. (1704–76.) A Doncaster clockmaker, who removed to Handsworth, Sheffield (1740–42), where he perfected his process of melting blister steel and Swedish wrought iron in clay crucibles heated by means of a coke furnace, and was thus the originator of *cast steel.* (See CRUCIBLE STEEL PROCESS.)

Huntsman Process. (See CRUCIBLE PROCESS.)

Husgafvel's Process. A method of direct reduction of the ore developed from the *Stückofen* process about 1887. The furnace was about 26 ft. high, 5 ft. wide at the boshes and 4 ft. wide at the throat. It had double air-cooled iron walls, separated by a spiral diaphragm, through which the air was passed. The hearth was a movable cast iron box, mounted on wheels and standing on a lifting platform. The furnace was charged with charcoal and ore exactly as a blast furnace is charged, and the reduction took place in the same way, excepting that the temperature was lower owing to the cooling action of the walls and the higher charge of ore. The iron did not carburize to any great extent and the iron that collected at the bottom was malleable. Means for regulating the carbon content were effected by size of ore charge, blast temperature and position and direction of the blast.

Hybinette Process. A process used for refining of crude nickel anodes. These are placed in reinforced concrete tanks lined with asphalt. The nickel anodes are dissolved electrochemically and the impurities such as copper and iron, pass into solution. The cathodes are surrounded by bags of closely woven canvas duck, fastened on wooden frames, and pure nickel electrolyte is passed continuously into them in order to maintain a higher solution level inside the cathode compartment than outside. By this means, the pure solution flows through the pores of the bags, thus preventing the ions of copper, etc., in the solution in the anode compartment from migrating into the cathode compartment, depositing on the cathode and preventing the refining process from taking place. The electrolyte in the anode compartments is drawn off continuously and is purified in the copper cementation and iron precipitation departments before being returned to the cathode compartments of the nickel deposition tanks. (I. 58.)

Hydragyrum. The Latin name for *mercury*, hence the symbol *Hg*.

Hydrated. Containing chemically combined water.

Hydrated Lime. This is produced from limestone by burning to remove the carbon dioxide and then slaking to convert the calcium oxide thus formed into calcium hydroxide.

Hydrates. Substances holding water in the molecular form (H_2O), or as water of crystallization. There are mono-, tri-, tetra-, penta-, hexa-, and hepta-hydrates representing respectively 1 to 7 molecules of H_2O to 1·0 of the substance.

Hydraulic Bulge Test. (See BULGE TEST.)

Hydraulic Descaling. The descaling of hot steel by water sprays. (F. 2.)

Hydraulic Fettling. (See HYDRO-BLAST.)

Hydraulic Flattening. (*Patent Flattening.*) The flattening of sheet by means of stretching.

Hydraulic Piercing. Hot forging by hydraulic power in which a billet is partially pierced to form a hollow cylinder preparatory to being elongated and formed into a tube. (See also PIERCING.)

Hydraulic Pipe. Pipe used for the conveyance of a liquid under pressure in connection with hydraulic machinery.

Hydraulic Weld Process. (*Water Gas Welding.*) A process for making large diameter welded tubes in which a steel plate is bent into cylindrical shape in bending rolls. The overlapping edges are heated for short distances to welding temperature and subsequently welded by pressing them together by hydraulic power. The heating and pressing is repeated until the length is welded. The tube is then heated all over and passed through rounding rolls. For certain sizes two plates may be required to make the necessary circumference.

Hydraulics. The science relating to the flow of fluids.

Hydrides. (*a*) Metallic hydrides, e.g. titanium-, zirconium-, thorium-, columbium- and tantalum-hydrides, are stable at room temperature, non-hygroscopic and can be preserved in air indefinitely since they do not oxidize. When heated in a vacuum or non-oxidizing atmosphere above 177° C. they gradually dissociate and give off pure hydrogen and metal. (*b*) Chemical hydrides, lithium aluminium hydride, sodium hydride, and calcium hydride, are comparatively new compounds that are rapidly finding important uses in many industries. A few of the applications are: lithium aluminium hydride used for the reduction of organic and inorganic compounds, sodium hydride used for condensation reactions. Calcium hydride is an excellent source of hydrogen and may be used as a reducing agent, a drying agent where super drying is required, or as a condensing agent. (M. 96.)

Hydrik Process. A commercial process for the production of hydrogen by reaction of caustic soda on aluminium.

Hydro-Blast. (*Hydraulic Fettling.*) A method of removing sand cores from heavy castings. Jets of high pressure water with entrained sand are used, the water pressure being 1250 lb. per sq. in. About 25 gallons of water per minute pass through the gun and about 70 lb. of sand are entrained per minute. Equipment is provided for reclaiming the sand with the fines eliminated. (M. 100.)

Hydrochloric Acid. (*HCl.*) (*Muriatic Acid.*) Aqueous solution of hydrogen chloride, a strong acid, fuming when concentrated; the concentrated acid of common use is 35% HCl and of specific gravity 1·18.

Hydrodynamic Process. A process for forming shallow sweeps and shapes and for drawing cone-shaped and tapered stampings in one operation, by the use of a fluid punch. (W. 34.)

Hydrofinish. The liquid blast cleaning and finishing of dies. In this process, the surface is blasted with a high-velocity stream of non-metallic abrasive particles suspended in an aqueous solution. As the suspension is delivered to the nozzle by a circulating pump, velocity is imparted by compressed air. (S. 132.)

Hydrofluoric Acid. (*HF.*) A clear, colourless, fuming corrosive liquid, which owing to its characteristic reaction with silica, is used as a chemical reagent. The acid is stored in wax containers, and produces severe sores if allowed to come into contact with the skin.

Hydroforming. In this operation, the material is formed over the die by a flexible diaphragm backed by oil-pressure. Units can be formed in a single operation, including the side embossing and offsetting. There is little abrasive wear in the die, which may be of metal, or wood, and *springback* of the shape is eliminated. The method has been used for development of jet engine parts where frequent change of design is required with a minimum of retooling. (D. 5.)

Hydrogen. (*H.*) *Atomic weight* 1·008. A colourless, odourless, tasteless gas. The lightest substance known. It is inflammable, and combines with oxygen to form water. The *molecule* is diatomic, i.e. contains two atoms (H_2). Hydrogen dissolves in liquid steel, the solubility being considerably greater than in solid steel. Thus, if more than a limiting amount is present, the excess will be liberated on solidification, giving a *wild* ingot. If the hydrogen content is too low for this to happen, trouble from the presence of hydrogen may still arise, particularly in ferritic steels, since dissolved hydrogen in solid steel causes loss of *ductility* and is a factor in the formation of *hair-line cracks*. The hydrogen can be removed by prolonged *soaking* at temperatures of 500° to 600° C. by a process of *diffusion* outwards from the centre. In large masses, however, the removal is very slow. *Acid open hearth* steel is usually lower in hydrogen than basic *electric steel*; the respective hydrogen contents are, in general, 3 to 5 millilitres of hydrogen /100 grams of steel and 4 to 7 millilitres /100 grams (1 millilitre of hydrogen per 100 grams of steel is approximately 0·00009%). A ferritic steel with over 8 millilitres/100 grams may give unsound ingots; an austenitic steel, however, will give sound ingots with 12 millilitres/100 grams. (See also FLAKES.) (B. 17a.)

Hydrogen Attack. (See HYDROGEN EMBRITTLEMENT.)

Hydrogen Brazing. A method of furnace brazing in a hydrogen atmosphere, thus eliminating oxidation.

Hydrogen Embrittlement. (*Hydrogen Attack.*) Loss of *ductility* caused by the absorption of hydrogen in steel and sometimes encountered in *acid pickling* of sheet steel.

Hydrogen Loss. In *powder metallurgy*, the loss caused in the weight of metal powder or of a compact when a representative sample is heated for a specified time and temperature in an atmosphere of purified hydrogen; broadly, a measure of the oxygen content of the sample when the test is applied to materials that contain only such oxides as are reducible with hydrogen, and no other *hydride* forming element. (A. 27.)

Hydrogen Swells. Bulges formed in the tinplate containers of canned fruit by the hydrogen produced internally. (H. 63.)

Hydrogenium. The name has been used for hydrogen absorbed in metal.

Hydrohaematite. (See TURGITE.)

Hydrolysis. A reaction wherein water effects a double decomposition with another compound, hydrogen going to one component, hydroxyl to the other.

Hydromatic Welding. (See PRESSURE-CONTROLLED WELDING.)

Hydrometallurgy. (*Wet Metallurgy.*) The extraction of metals from their ores by *leaching* with an aqueous solvent which dissolves the metal without attacking the *gangue*.

Hydrometer. An instrument for the measurement of the specific gravity or density of a liquid. A typical hydrometer consists of an air-filled bulb surmounted by a graduated stem. Below the air bulb is a smaller one containing mercury or lead shot in an amount sufficient to make the hydrometer float in an upright position. The depth to which the instrument sinks depends on the density of the liquid under test and therefore the density can be read off from the calibrated scale, on the upper stem of the hydrometer. (See also BAUMÉ HYDROMETER and TWADDEL HYDROMETER.)

Hydrometrograph. An instrument for determining and recording the quantity of water discharged from a pipe, orifice, etc., in a given time.

Hydropaste. An ingot mould coating consisting of flake aluminium plus a binding medium. It is claimed that this coating does not give off fumes, and approaches tar in performance and cost. (G. 31.)

Hydrophore. An instrument for obtaining specimens of water from any desired depth, as in a river, lake or ocean.

Hydropyrometer. (*Water Pyrometer* or *Calorimeter.*) An old type of pyrometer in which a ball of metal of known weight and specific heat is exposed to the heat of the furnace or of the metal bath, and then rapidly transferred through a clay tube to an insulated vessel containing a known quantity of water at a known temperature. The heat of the furnace or bath is then calculated from the increase in temperature of the water.

Hydrostatic Testing. The testing of a hollow part, e.g. a tube, for tightness by means of water, oil, or other liquid under pressure.

Hyglo. A crack detection process. It consists in placing the articles to be examined in a wire basket and dipping them for about two minutes in a covered high-sided tank containing the fluorescent solution which is maintained at a suitable temperature. The basket is then raised above the level of the solution for about half a minute, during which the vapour of the solvent surrounds the articles and drains away or quenches the fluorescence on the surface. The fluorescent material in the defects, however, remains and examination in ultra-violet light reveals the defects as vivid green lines or spots against the dark background of the non-fluorescent parts of the article.

Hygrometer. An instrument for the measurement of the humidity of the air.

Hygroscopic. Descriptive of a substance which absorbs water from the air.

Hypercarb Process. A process of case hardening. Steels are treated at elevated temperatures with a regulated atmosphere of hydrocarbon and carbon monoxide which gives a controlled high carbon case containing up to 1·2% C. By preheating the carburizing gases to about 900° C. a very rapid and clean carburizing action is obtained. By adjustment of the soaking time and gas composition, the carbon content of the case may be varied for different depths of case.

Hypereutectoid Steel. Steel containing carbon in excess of the *eutectoid* composition of about 0·83%. The structure of such steels in the normalized condition consists of a *pearlitic* matrix with *cementite* along the grain boundaries. (See Plate VII (d).)

Hypersonics. Synonymous with *ultrasonics*.

Hypersonic Analyser. A device used in non-destructive testing which consists of a sound generator which sends a beam through the specimen to be tested. The specimen, depending on its properties, modifies the beam, and the resulting energy pattern is picked up on the side

opposite the generator by means of a microphone. It is claimed that it so selects radiation frequencies and electro-acoustic designs that the resultant beams through the material are highly modified by a given type of flaw in any given material. (M. 31.)

Hypoeutectoid Steel. Steel containing less than about 0·83% carbon, i.e. below *eutectoid* composition. The structure of such a steel in the normalized condition consists of a mixture of *ferrite* and *pearlite*, the proportion of pearlite increasing with the carbon content, that is under the same conditions of cooling. (See Plate VII (a), (b), and Plate VIII (a), (b), (c), and (d).)

Hysteresis. (*a*) (*Cooling Lag.*) The difference between the critical points on heating and cooling due to the tendency of physical changes to lag behind temperature changes during heating and cooling operations. (*b*) (See MAGNETIC HYSTERESIS).

Hysteresis Curve. A curve showing the relation between the *magnetizing force* and *flux density* in a sample of iron or steel, the curve being taken with ascending and descending values of magnetizing force. The resulting closed curve is called a magnetic *hysteresis loop*.

Hysteresis Loop. (See HYSTERESIS CURVE.)

Hysteresis Loss, (P_h). The power expended in a magnetic material as a result of magnetic hysteresis, when the magnetic induction is cyclic. (A. 28.)

Hysteresis, Magnetic. The property of a magnetic material by virtue of which the magnetic induction for a given magnetizing force depends upon the previous condition of magnetization. (A. 28.)

I

I. (*a*) Chemical symbol for *iodine*. (*b*) A French symbol for a plane type of fracture which occurs in a direction perpendicular to the axis of the piece. (*c*) Abbreviation for inclined welding position.

I.A. *International Ångström.*

Ib. Abbreviation for *ibidem.*

I. Beam. (See STRUCTURAL SHAPES.)

Ibid. Abbreviation for *ibidem.*

Ibidem. In the same book or chapter.

I.C. Code letters used in the manufacture of *tin plate* to indicate a standard thickness of 0·0213 in.

I.C.C. Interstate Commerce Commission (U.S.A.).

I.C. Couple. *Iron Constantan Couple.*

Ice Spar. (See CRYOLITE.)

Ice Stone. (See CRYOLITE.)

I.C. Substance. (See SUBSTANCE.)

I.C.W.A. Institute of Costs and Works Accountants.

Ideal Diameter. (See GROSSMAN'S HARDENABILITY CHART.)

Ideal Quench. A theoretical quench in which the surface of the hot metal on immersion instantly drops to the temperature of the quenching medium.

Ideptometer. An instrument for the rapid checking of the analysis of steel bars against that of a standard bar of known analysis. The principle employed is that of measuring the thermo-electric *e.m.f.* generated when a junction between two dissimilar metals is heated. The bar to be tested is placed so that it rests across, and in contact with, the upper surface of the standard bar; heat is applied and leads are connected to the Identometer which indicates the thermo-electric *e.m.f.* on a suitable calibrated dial. If the two bars are of the same analysis no e.m.f. will be generated, but if they are of different composition, the pointer will immediately indicate this. (S. 119.)

Idiomorphic Crystal. A perfect crystal exhibiting geometric arrangement of plane faces, observed occasionally with certain constituents or intermetallic compounds in the microstructure of cast alloys. The normal crystals, generally called grains in metallography, are of the imperfect or *allotriomorphic* type, since the outward form is determined more or less by the surroundings. (A. 27.)

Idle Rolls. *Back-up rolls*, i.e. rolls which are used to support working rolls and are not driven.

Idler. (*a*) A roller used to support and guide a rope, belt or chain. (*b*) A supporting or back-up roll.

Idling. The rolling of heavy steel sections at relatively slow speeds.

I.E.C. International Electrochemical Commission.

I.E.E. Institution of Electrical Engineers.

I.G. An abbreviation for inert gas welding, i.e. *shielded inert gas metal arc welding.*

Igewsky's Reagent. A solution consisting of 5% picric acid in absolute alcohol used as an etching reagent for carbon steels.

Ignition Alloy. (See PYROPHORIC ALLOYS.)

Ihrigizing. A method of producing a high silicon (about 14% silicon) case on iron and steel. The metal parts, together with a suitable quantity of silicon carbide, are charged into a rotating retort through which is passed a con-

tinuous stream of chlorine, and the furnace is heated to about 1000° C. A treatment of about 2 hours is required to produce a case of 0·035 in. Ihrigized iron or steel is said to have an excellent resistance to corrosion by acids, chlorine and salt spray; to resist scaling in oxidizing atmospheres up to 980° C.; and to be particularly resistant to galling and seizing, either on itself or on other metals. (I. 2.)

IK. (See INKROM PROCESS.)

IK Steels. (See INKROM PROCESS.)

I.K.A. Devoorde Rust and Scale Removing Equipment. This consists of a cage containing a number of axial shafts arranged around its periphery which is rotated by means of an electric motor, the drive being taken through a flexible shaft. On each of the axial shafts a rust or scale-removing element is mounted; according to the type of deposit to be removed, these elements consist of wire brushes or toothed wheels. The scale-removing element is a loose fit on its shaft, a play of 0·02 in. to 0·08 in. being allowed. As the cage rotates, these elements are flung outwards by centrifugal force; as they strike the surface to be cleaned they rebound inwards, and as a result the deposit is subjected to a constant hammering action, which rapidly loosens and removes it, leaving a smooth surface. The cage rotates at 3000 r.p.m. (S. 20.)

Ikeda Short Time Resistance Test. An electrical resistance test, developed by Ikeda of Tohoku University, in which the resistance of a fatigue specimen is measured while it is being subjected to cycles of stress of various magnitudes. A distinct change of resistance is noted at a stress which is said to check quite closely with the long time endurance test. (M. 160.)

Il. Chemical symbol for *Illinium.*

Illinium. (*Il.*) (*Florentium.*) A metallic element of the cerium group of rare earths. *Atomic weight* 147. The element itself has not been isolated. It was discovered in 1926.

Illinois Inclusion Count Method. In this method, the minimum number of samples taken from a heat is nine, these being from the top, middle and bottom billets of the first, middle and last ingots. A polished specimen of longitudinal section is used. The inclusions are measured with a micrometer ocular and recorded. The magnification used is 100 diameters. The inclusions are classified into five groups: small, medium, large, double large and triple large, the "weights" given to these being 0, 1, 2, 4, and 6, respectively. No attempt is made to express the results in terms of absolute values, such as the area or number of inclusions per unit area. Instead, a simple number is assigned to each specimen, this being derived by adding the "weights" of all the inclusions found. The sum of these numbers from all of the specimens of a heat divided by the number of specimens is then used as the index number of cleanliness of the heat of steel. (E. 77.)

Ilmenite. (*Chrichtonite, Menaccanite.*) A titanic iron ore ($FeO.TiO_2$) and one of the two most important titanium minerals. (See also RUTILE.) The chief producing countries are U.S.A., India and Norway.

Ilmenorutile. A black variety of *rutile*, consisting essentially of titanium oxide but containing up to about 10% ferric oxide.

Image. In X-ray diffraction patterns, by analogy with optics, a recognizable copy of the source of X-rays or of any aperture defining the X-ray beam. (A. 27.)

Immersed Ultrasonic Inspection. A method in which the scanning crystal is submerged in a liquid to minimize multiple reflections. The advantages claimed are a reduction in surface smoothness requirements; ability to focus the beam into fillets, complex surfaces and other areas not flat enough for contact crystals; and ability to use higher frequency crystals. (S. 83.)

Immersion Coating. (See METAL REPLACEMENT.)

Immersion Heating. Heating in a liquid such as a bath of molten lead, fused salt or oil, thus ensuring that the part is uniformly heated overall.

Immersion Plating. (See METAL REPLACEMENT.)

Immiscible. Incapable of being mixed to form a homogeneous substance; usually applied to liquids; e.g. oil and water are immiscible.

Impact Abrasion Hardness. A method of determining wear resistance involving a standardized pressure blasting of a plane polished surface with a constant abrasive at constant pressure, followed by an accurate measurement of the depth of the impression produced. (R. 27.)

Impact Cleaning. A term covering the processes of *sand* and *shot blasting*.

Impact Extrusion. In this method an unheated slug of metal is used which is small in comparison with the billets employed in ordinary *extrusion*. The slug is fixed in a shallow die, and subjected to a sudden blow by a punch over which the metal is caused to flow through the annular orifice between the

punch and the die wall. The process allows the manufacture in one operation of products of simple shapes which would require several successive operations by other techniques. The method is used primarily for the production of hollow or very deeply recessed parts whose wall thicknesses are small in comparison to their lateral dimensions. (H. 15.)

Impact Failure. Instantaneous failure under suddenly applied stress.

Impact Forging. A method of cold forming in which a carefully-sized blank is placed in a die cavity. A punch is forced into the die cavity under extremely high pressure, causing the blank to extrude either forward through a hole in the die (away from the punch) or backward (up and around the punch). The blank is thus cold-worked to shape with the improvement in mechanical properties and refined grain flow typical of other types of forgings. The method is applicable to aluminium alloys rather than steel. (D. 18.)

Impact Resistance. (See IMPACT TEST.)

Impact Strength. The resistance a material is capable of developing against impact blows; usually expressed as the ft. lb. of energy necessary to break a standard specimen. (See IZOD, FRÉMONT and CHARPY TESTS.)

Impact Tensile Testing. (See TENSILE IMPACT TEST.)

Impact Test. A test to determine the resistance of a material to a suddenly applied stress, i.e. shock. A *notched test piece* is normally employed and the testing machines in most general use are the IZOD, CHARPY, FRÉMONT, and GUILLERY. The resistance is usually reported as the energy in ft.-lb. or kilogram-metres to fracture the test piece or as the energy per unit section behind the notch. (See also TENSION IMPACT and STANTON TEST.)

Impact Value. The total energy required to break a standard specimen by a single blow under standard conditions, e.g. IZOD, CHARPY and MESNAGER.

Impacting. A method of forming metal carried out in the *Chambersburg Impactor.* This hammer is equipped with two opposed members (impellers) that carry the dies for forming the workpiece. The reciprocating impellers, of equal mass, are driven together in a horizontal direction by compressed air in similarly opposed, double acting cylinders. Stock is positioned in the impact plane between the two dies, and the energy of the impellers is absorbed in deforming and heating the workpiece. (M. 48.)

Impedance. The total opposition to the flow of an alternating current, i.e. the combined effect of resistance and reactance. It is a quantity expressed in ohms.

Imperfect Root Penetration. (*Lack of Penetration, Incomplete* or *Poor Penetration.*) The gap left by the failure of the weld metal to fill the base of a weld. In arc welding the defect may be due to the use of an electrode of poor penetrating power, too small a current, or too small an electrode.

Imperial Blacking. (See BLACKING.)

Impfing. Seeding a liquid with a small crystal in order to induce crystallization.

Impingement Attack. Corrosion associated with turbulent flow of a liquid. For some metals the action is considerably accelerated by entrained bubbles in the liquid.

Import Certificates. Applications for Import Certificates should be made to the Board of Trade, Import Licensing Branch, Romney House, Tufton Street, London, S.W.1.

Import Licensing Branch of the Board of Trade, Romney House, Tufton Street, London, S.W.1. This deals with licences for import of goods into the United Kingdom.

Impoverishment. Loss of any constituent from an alloy or localized areas of an alloy by *oxidation, liquation, volatilization,* or changes in the solid state. The term *depletion* is also used, particularly in referring to the lowering of the concentration of *solute* in a *solid solution,* around particles precipitated from solid solution. (A. 26.)

Impregnated-Tape Metal Arc Welding. A process wherein coalescence is produced by heating with an electric arc between a metal electrode and the work. *Shielding* is obtained from decomposition of an impregnated tape wrapped around the electrode as it is fed to the arc. Pressure is not used and filler metal is obtained from the electrode. (A. 37.)

Impregnation. (*a*) The process of filling the pores of a sintered compact with a liquid, such as a lubricant; also the process of filling the pores of a sintered or unsintered compact with a metal or alloy of lower melting point. (*b*) The process of mixing particles of a non-metallic substance in a powder metal matrix as in diamond impregnated tools. (*c*) The process of coating a sintered compact with another metal by burying and heating the compact in a powder of the second metal. (*d*) The process of diffusing a second metal, e.g. chromium or carbon, into the surface of a metal. (See CEMENTATION.)

Impression. (*a*) That portion of the *die* which has been machined to the desired shape of the *forging*. (*b*) The indentation made in hardness testing.

Impulse Welding. (See PULSATION WELDING.)

Impurities. Those elements or compounds in metal or steel whose presence is accidental and which have not been added by design.

Impurity Line. (See ANALYSIS LINE.)

I.M. Sand. Sand occurring at the top of the measures in the quarry between Bournemouth and Poole. It is the base sand, used with the clay occurring immediately below the sand, in the production of the Dorset moulding sand.

Incandescent Carbon Brazing. (See RESISTANCE BRAZING.)

Inch Pound. A unit of energy equal to that required to lift 1 lb., 1 in. high.

Inch Ton. A unit of energy equal to that required to lift 1 ton, 1 in. high.

Inches Penetration Per Month. (*IPM.*) (See INCHES PENETRATION PER YEAR.)

Inches Penetration Per Year. (*IPY.*) A value indicating the depth of corrosion attack on a specimen submitted on one side only to a specified corrosive for 365 days of 24 hours. *Inches Penetration per month* (*IPM*) is taken as one-twelfth of the IPY.

Inches to Millimetres. (See Appendix I.)

Inching. The operation of easing a drawing machine.

Inchromizing. (See INKROM PROCESS.)

Incidental Element. (*Tramp Element.*) An element present in the steel or alloy and not intentionally added.

Included Angle. (See GROOVE ANGLE.)

Included Plan Angle. (See RAKE.)

Inclusion Count. A means of evaluating the inclusion content of any particular steel. Numerous methods have been developed and are listed under their separate headings.

Inclusions. (*Sonims.*) Non-metallic particles found in steel. They represent the products of deoxidation reactions, i.e. oxides, silicates and sulphides, which have not had the opportunity to coalesce and rise out of the liquid steel, together with fluxed refractories and slag introduced during tapping and casting.

Incomplete Interrun Penetration. A gap occurring in a multirun weld where the weld metal fails to fill a crevice formed by a previous run or runs (usually at the toes of the underlying run or runs). It appears in a radiograph as a dark, intermittent or continuous line which may have both edges wavy or one edge straight and the other wavy. (B. 105.)

Incomplete Root Penetration. (See IMPERFECT ROOT PENETRATION.)

Incorrect Penetration. In welding, this refers to an insufficient deposit of the electrode and insufficient penetration of the arc. In the case of light gauge welding, excessive penetration is likely to occur, resulting in *burning through the plate*.

Increasing Load Tester. (See REPEATED SCRAPE ABRASION TESTER.)

Incremental Induction. (See INDUCTION, INCREMENTAL.)

Incremental Permeability. (See PERMEABILITY, INCREMENTAL.)

Indentation Hardness. The resistance of a material to *indentation*. This is the usual type of hardness test, in which a pointed or rounded indenter is pressed into a surface under a substantially static load. (See also HARDNESS.)

Indentation Test. *Hardness* tests showing resistance to penetration, e.g. *Brinell, Rockwell, Monotron, Firth Hardometer*, or *Vickers Tests*.

Indentometer. A direct-reading portable hardness tester which gives direct readings on various Rockwell scales. Loads are instantly variable by the turn of a hand wheel and, with the standard model, loads of up to 150 kg. can be applied. It uses a 120 degree cone diamond indenter. Alternatively, either a $\frac{1}{16}$- or $\frac{1}{8}$-in. diameter steel ball may be utilized. Readings on the Rockwell C and B scales, and also the F, G, E, K and A scales, are obtainable. Loads are applied via a hydraulic pressure assembly consisting of a diaphragm unit filled with fluid coupled to a calibrated dial pressure gauge mounted on the top of the instrument. The depth of the impression is measured by a lever mechanism coupled to a direct reading hardness recording dial on the face of the instrument. The dial gauge is graduated in units of 0·002 mm. (or one point on the Rockwell hardness scale). (M. 116.)

Index Diagram. A chart based on an X-ray diffraction pattern and permitting the assignment of indices to the families of planes responsible for the maxima of intensity in the pattern. (A. 27.)

Index of Refraction. (*Snell's Law.*) The ratio of the velocity of light in a substance as compared to the velocity of light in a vacuum.

Index Point. In *spectrographic analysis*, the index point is that concentration of the element being determined at which the intensities of the radiations producing the analysis and internal standard lines are equal.

Indian Railway Standard Specifications. Available at the Office of the High

Commissioner for India, Publication Department, India House, Aldwych, London, W.C.1.

Indian Steel. (See WOOTZ.)

Indicator. (*a*) A substance that reveals the presence of a certain constituent. In a more restricted sense the term refers to a substance which indicates the extent of a reaction between two reagents. In *volumetric analysis*, the indicator is added to make visible the point at which the reaction becomes *stoichiometric*. (*b*) An instrument used in conjunction with a thermocouple or other device for measuring temperatures.

Indices. (See CRYSTAL INDICES.)

Indices of Crystals. (See MILLER INDICES.)

Indigo Copper. (See COVELLITE.)

Indigometer. An instrument for ascertaining the strength of an indigo solution, as in *volumetric analysis*.

Indirect Arc Furnace. (See ARC FURNACE.)

Indirect Extrusion. (*Inverted.*) An extrusion process in which the metal is forced back inside a hollow ram that pushes the die. (A. 27.)

Indirect Fired Furnace. A furnace in which combustion takes place in a separate chamber and the material being heated is not in direct contact with the fuel.

Indium. (*In.*) *Atomic weight* 114·76. *Specific gravity* 7·31. *Melting point* 156° C. A silver-white metal, having a Brinell value of less than one (·85). It is soft, ductile and very malleable, and is used in the plating of silver to produce an untarnishable alloy. When added to cadmium alloy bearings it markedly reduces the corrosion in acidified lubricating oils without detriment to the mechanical properties. Indium additions to titanium give some increase in strength with a slight decrease in ductility. Addition of indium to *Wood's metal* alloys lowers their melting point by about 1·45° C. for every 1% of indium, with the lowest melting point at 47° C. for 19·1% indium. An alloy containing equal amounts of tin and indium is used in glass sealing applications. This alloy is capable of wetting glass and of making glass-to-glass or glass-to-metal seals.

Inductance. (*a*) The resistance offered to a change in *e.m.f.* in a circuit, due to the self-induced e.m.f. caused by variation of the magnetic field, the direction of the latter e.m.f. being such as always to counteract changes in the current. (*b*) An electrical unit in which this property is pronounced.

Inductance, Self. (*L.*) That property of an electric circuit which determines the flux linkage produced by a given current in the circuit. If ferromagnetic material or eddy currents are present, the inductance must be regarded as a function of the current, its rate of change, and the magnetic history of the material. (A. 28.)

Inductile. Lacking *ductility*.

Induction. (See MAGNETIC FLUX DENSITY; INDUCTION, MAGNETIC; INDUCTION, NORMAL.)

Induction, Biased. (B_b.) The algebraic means of maximum and minimum values of the magnetic induction in a magnetic material during a cycle, while it is subjected to a biasing magnetizing force. (A. 28.)

Induction Brazing. A *brazing* process in which the heat is generated by eddy current losses and hysteresis losses and the depth of the heated zone is a function of the frequency of the current passing through the inductor coil. (C. 15.)

Induction Curve, Intrinsic. A curve depicting the relation between intrinsic induction and magnetizing force. (A. 28.)

Induction Curve, Normal. A curve depicting the relation between normal induction, and magnetizing force. (A. 28.)

Induction Furnace. (See HIGH FREQUENCY FURNACE.)

Induction Hardening. A process of hardening steel by heating it, by means of an alternating magnetic field, to a temperature within or above the transformation range, followed immediately by quenching. This process may be applied to both surface hardening and full hardening. (See also TOCCO PROCESS.)

Induction Heating. Heating by means of an alternating magnetic field. An induction heating circuit is fundamentally a transformer wherein the inductor carrying the alternating current is a primary and the substance to be heated is made the secondary by placing it within the confines of the loop formed by the inductor, there being no contact or connection between the two. The current flowing through the inductor sets up magnetic lines of force which thread through the surface of the material being heated and induce a flow of energy therein. If magnetic material is involved it may be assumed to be made up of many small particles of iron which tend to become polarized with a north and a south pole lined up with the polarity of the field produced within the inductor by the flow of current. The polarity of this field changes many times per second with

the alternation of the current necessary for high frequency heating, and the tendency for these small magnets to realign themselves with the changing field polarity is resisted by the metal, and internal molecular friction is developed which dissipates itself in the form of heat. (O. 4.)

Induction, Incremental. ($B\Delta$.) One-half of the algebraic difference of the maximum and minimum values of the magnetic induction during a cycle in a magnetic material which is subjected to a biasing magnetizing force. (A. 28.)

Induction, Intrinsic. (B_i.) (*Ferric Induction.*) The excess of the induction in a magnetic material over the induction in vacuum, for a given value of the magnetizing force. (A. 28.)

Induction, Magnetic. (B.) (*Magnetic Flux Density.*) Flux per unit area through an element of area at right angles to the direction of the flux. The c.g.s. unit of induction is called the *gauss* (plural gausses). (A. 28.)

Induction, Normal. (B.) The limiting induction, either positive or negative, in a magnetic material which is in a symmetrically cyclically magnetized condition. (A. 28.)

Induction Period. In a chemical reaction that period before reaction commences.

Induction, Remanent. (B_d.) (See REMANENCE.)

Induction, Residual. (B_r.) The magnetic induction corresponding to zero magnetizing force in a magnetic material which is in a symmetrically cyclically magnetized condition. (A. 28.)

Induction, Saturation. (B_s.) The maximum intrinsic induction possible in a material. (A. 28.)

Induction Soldering. The heat necessary for soldering by induction is induced in the joint by eddy currents when the parts are placed in or near the high frequency coil. Close control of temperature without risk of local overheating gives this method special merit. The solder and flux in any suitable form are preplaced. Batch or continuous operation on belts or rotating tables can be done equally well. Careful design of the joint and the coil set-up are necessary to avoid shielding the work from the energizing coil. The three common sources of high frequency current used for induction soldering are the motor-generator, resonant spark gap and vacuum tube oscillator. (M. 9.)

Induction Welding. A welding process wherein coalescence is produced by the heat obtained from resistance of the work to the flow of induced electric current, with or without the application of pressure. (A. 37.)

Inductive Stirring. In this operation, a stirrer is placed under the non-magnetic bottom plate of the furnace, and works on two phases. The electric currents in the two phases induce electric current paths in the liquid steel bath. At the same time the two phases generate a moving magnetic field, which reacts upon the steel composing the current paths with forces parallel to the furnace bottom. The result is that those parts of the bath which are close to the furnace bottom are set in motion in a direction parallel to the bottom. The slagging-off operation is considerably facilitated when the stirrer is in operation. The deslagging is carried out simply by raking off the slag from the area just inside the furnace door. (F. 25.)

Inductometer. An instrument or apparatus for ascertaining the force of electrical induction or for comparing the specific inductive capacities of various substances.

Induflux Method. A method of determining the relative fatigue in steel rods by measuring the differences in their magnetic properties. (S. 144.)

Industries Branch, Board of Trade, Horse Guards Avenue, London, S.W.1. A department which assists United Kingdom manufacturers to appoint representatives or agents abroad.

Industries and Manufacturers Department, Board of Trade, Horse Guards Avenue, London, S.W.1.

Inert Arc Welding. (See INERT GAS ARC WELDING.)

Inert Gas. A gas which will not support combustion or sustain any chemical reaction, e.g. argon or helium.

Inert Gas Arc Welding. (*Shielded Inert Gas Metal Arc Welding.*) (*SIGMA Welding.*) In this process, an electric arc of extremely high current density is formed between a virtually non-consumable electrode, commonly tungsten, and the work. The arcing terminal of the electrode and the resultant pool of fused metal formed in the work by the arc are surrounded by a shield or blanket of inert gas. The inert atmosphere is provided by directing *helium* (*Heli-Arc*) or *argon* (*Argon-Arc*) into the weld arc via a sheath surrounding the electrode. In the United Kingdom argon is used but in the U.S.A. helium is available as a natural gas. The weld metal is thus protected from oxidation and other atmospheric contamination, and due to this gas protection the finished welded surface is smooth, clean and uniform. In filler rod welding the

tungsten electrode is replaced by a filler rod of the material to be welded. (M. 56, M. 134.)

Inert Gas Carbon Arc Welding. A process in which fusion is obtained by heating with an electric arc between a carbon electrode and the article to be welded. Shielding is obtained from an inert gas such as *argon*, or *helium*. The application of pressure and/or the use of a filler rod are optional. (A. 37.)

Inert Gas Tungsten Arc Welding. Inert gas arc welding with a tungsten electrode (i.e. *Inert Gas Arc Welding*).

Inertia. The resistance offered by a body to a change in its state of rest or motion.

Infiltration. The process of filling the pores of a sintered or unsintered compact with a metal or alloy of lower melting point by capillary action. The process has long been used in the manufacture of electrical contacts, and it is now acquiring increased importance in the production of gas turbine blades made either from iron-copper or titanium carbide-nickel alloy. The operation is usually accomplished by *full dip immersion*, i.e. by total immersion of the compact in a liquid metal bath but other processes include *capillary dip*, in which the compact is partly submerged in the molten metal and *contact infiltration*, melting the solid metal whilst in contact with the compact.

Information Division, Board of Trade, Horse Guards Avenue, London, S.W.1.

Information Services. By inter-library co-operation, organized in eleven Regional Bureaux and the National Central Library, books and journals may be borrowed and enquiries answered, from the public and many other, libraries throughout the country. These would include the services of libraries such as the Science Library. Information is in general freely available from any of the fourteen research establishments of the *D.S.I.R.* Each of these maintains its own library and information service; publications can often be lent to other organizations when normal sources of supply fail. As an aid to the location of the appropriate establishment, a pamphlet entitled *Brief Guide to the Research Activities of D.S.I.R. and the Research Associations* may be obtained on application to D.S.I.R., Charles House, 5–11 Regent Street, London, S.W.1. Queries may also be sent direct to headquarters and the Department will then put the enquirer in touch with specialized sources of information or will endeavour to provide an answer itself when no suitable specialized source exists. D.S.I.R. also acts as the British National Information and Liaison Centre in connection with arrangements for international exchange of information. There is furthermore one other service available if other means fail: D.S.I.R. issues from time to time a free bulletin entitled *Unanswered Questions*, which is widely disseminated in the hope that someone somewhere will be able to provide the required information or make suggestions. Such enquiries should be sent to T.I.D.U., D.S.I.R., Cunard Buildings, 11 Regent Street, London, S.W.1. *"Aslib"* (formerly Association of Special Libraries and Information Bureaux) is an organization which exists to encourage the study of documentation and information services, and to assist the development of special libraries; it holds conferences and meetings and provides short training courses in information work. Aslib has an information department acting as a clearing house for enquiries of all kinds, whereby members can be put in touch with specialist sources of information among other members and elsewhere. Aslib also has a range of other useful services such as inter-lending arrangements and the provision of photo-copies or microfilm copies of virtually any published document; there is an index of unpublished translations of scientific papers held throughout the commonwealth, and these can be borrowed; the services of special translators can be arranged. Aslib publishes a number of manuals, guides to sources of information, etc., in addition to four periodicals dealing with documentation and information activities. Regional branches and subject groups provide further machinery for co-operative projects among members. The address is Aslib, 4 Palace Gate, London, W.8. (F. 6.)

Infra-Red Radiation Pyrometer. The instrument uses the fact that the ratio of the radiated energy in two wave-length bands received from a hot body is a measure of the body's surface temperature. As only a ratio is involved, the measurement is independent of the emissivity of the body if this does not vary with wave-length over the used range, the distance of the body from the source, and time of exposure. A lead sulphide photo-conductive cell is used for radiation detection. Temperatures down to 200° C. may be measured. (G. 13.)

Infra-Red Rays. Heat waves of longer wave-length than that of the visible spectrum. They have high heating value and have been used for drying green sand moulds. The equipment consists of frames carrying twenty

electric lamps with reflectors spaced 6 in. apart. The portability of the frames and the short drying time constitute the principle advantages of this method of drying. (D. 53.)

Infrasizer. An apparatus for air elutriation of very fine particles. (H. 30.)

Infusorial Earth. (*Diatomite, Fossil Flour, Kieselguhr, Mountain Meal, Mountain Flour, Tripolite.*) The very fine whitish powder composed of the siliceous skeletons of *diatoms*. Its uses extend to almost every industry, great quantities being used for the filtration of beers and other beverages, penicillin preparations, sugar, paints and rubber; it is used in heat insulation materials and in fireproof cements, and as an absorbent. About 25,000 tons of diatomite are imported into the United Kingdom each year, but in September 1953 a deposit of diatomite was opened up on the Isle of Skye, which is estimated to comprise about one million tons.

Ingaclad (Stainless-clad) Steel. A trade name for clad metal (see CLADDING) in which a thin layer (about 20%) of stainless steel has been bonded to a thicker base of mild steel.

Ingate. The opening through which metal is poured into the mould. It then passes along runners to the spaces made vacant by the withdrawal of the *patterns*. (See GATE.)

Ingot. A mass of metal cast into a *mould*. It differs from a *casting* in that it has to be *rolled* or *forged* to be made usable.

Ingot Iron. Iron of comparatively high purity, produced in the *open hearth furnace*, under conditions that keep down the carbon, manganese, and silicon content, e.g. *Armco iron*.

Ingot Moulds. Primarily, the function of an ingot mould is to provide a receptacle for the molten steel, which shall, after freezing, be in a form suitable for subsequent working. A further function of the mould is to abstract heat from the molten steel, and to dissipate it by radiation, or other means, from its outer surfaces. Moulds are generally of cast iron although a few steel moulds have been used with indifferent success. Those ranging in size from 3 to 6 in. square are often of the split or two-piece type to facilitate stripping, but moulds over 6 in. are usually of the solid type. These are generally of square section when the ingots are subsequently rolled into bars or billets, or used for making small forgings, and of rectangular section when used for rolling into slabs for subsequent rolling into sheet or strip. Larger ingots, used for making large forgings, are usually polygonal in section (generally octagonal, 8 sides, or duohexagonal, 12 sides). When the ingots are *top poured*, the moulds may be provided with a solid bottom, and when *bottom poured*, with a bottom with a central hole. Alternatively, the mould may be open at the bottom end in which case it is set on a cast iron or copper *stool*. Ingot moulds are usually tapered to facilitate stripping and may be used either big-end up or big-end down. (See Plate VI.)

Ingot Shell. (See DOUBLE SKIN.)

Ingot Stripper. A machine for extracting ingots from ingot moulds.

Ingot Structure. The arrangement of the *crystals* in an *ingot*. These usually comprise a thin outer layer of chill crystals, followed by a wider zone of columnar crystals with a central mass of *equiaxed crystals*.

Ingot Tipper. A device used in rolling mills for manipulation of ingots into the required position.

Ingotism. (*Pattern Effect.*) The extremely coarse dendritic structure which exists in unannealed ingots and castings. It is a term which is also used to describe the macro-structure of forgings which show core dendritic patterns. (H. 77.)

Inherent Grain Size. (See McQUAID EHN GRAIN SIZE.)

Inherent Restriking Voltage. In welding, the restriking voltage associated with a particular circuit and determined by the circuit parameters alone, its form being unmodified by the conditions in the gap.

Inhibitor. (*a*) (See PICKLING). (*b*) Any agent added to foundry sand for the purpose of restraining an undesirable chemical reaction. (A. 26.)

Initial Creep. (*Primary Creep.*) The early part of the time-elongation curve for creep, in which extension increases at a rapid rate. (A. 27.)

Injection Moulding. The injection of liquid metal or other material under pressure into moulds.

Ink Print. (See CONTACT PRINTING.)

Inkrom Process. (*IK.*) (*Inkromierung Process.*) (*B.D.S Process.*) A process of *chromizing* in which the steel specimens to be treated are packed in ceramic containers filled with chromium chloride, charged into a furnace and heated. Different types of furnaces are used according to dimensions and shape of the pieces to be treated. The type of steel is of paramount importance, a high carbon steel giving unfavourable diffusion zones. Special *IK Steels* developed for the process are mild unalloyed steels with tensile strengths of about 20 to 30 tons per sq. in. The steels can be welded or soldered. The former is carried out

before diffusion treatment, the latter after. With regard to surface-corrosion resistance, the diffusion treated steels are claimed to be equal to a 30% chromium alloy steel, and even a 0·1 mm. diffusion zone shows a chromium content of 13%. The close bond obtained between the iron and chromium allows cold forming, pressing, and drawing without detrimental effect to the protective qualities of the surface. The treated surfaces are resistant to scaling up to 850° C. for long periods and at even higher temperatures for shorter periods. Forgings and steel castings can also be treated with this process. (I. 56.)

Inkromierung Process. (See INKROM PROCESS.)

Inlet Wire. The wire entering the first die of a drawing machine.

Inoculants. Additions made to cast iron in the *inoculation* process.

Inoculated Cast Irons. Cast irons to which, whilst still in the molten state, an addition has been made for the purpose of modifying the microstructure and thereby improving the mechanical and physical properties. Two processes of *inoculation* have been patented. In both, the composition is such that if cast without treatment the iron would solidify just white, i.e. it would have no *graphite*. By providing an abundance of nuclei just before casting, the graphite formed consists of a large number of short stubby flakes, which do not seriously break up the continuity of the metallic matrix. In the *Meehanite* process, inoculation is performed by the addition of calcium silicide to the *ladle* or *cupola* spout (120 oz. per ton being the average addition). A number of grades are manufactured, each to suit castings of a given average section. In another process, the inoculant used is a mixture of ferro-silicon and nickel, and tensile strengths of 22 to 26 tons per sq. in. are obtained.

Inoculation. (*a*) The addition to a *supercooled liquid* of a crystal of the phase which is about to solidify. (See NUCLEI.) (*b*) (See INOCULATED CAST IRONS).

Inorganic Chemistry. The chemistry describing the preparation, properties and reactions of all the elements, and of all their compounds, with the exception of the compounds of carbon. However, the metal carbides, together with oxides and sulphide of carbon are included in inorganic chemistry.

INSDOC. Indian National Scientific Documentation Centre.

Insert. (*a*) A movable piece of steel placed in a die to fill a cavity or to replace a portion of the die with a quality of steel more suitable for the service required at that particular point. (*b*) In a casting a part formed from a second material, usually a metal, which is placed in the mould and appears as an integral structural part of the final casting.

Insert Core. Intricate cores are sometimes produced with an insert core, made and baked separately, rammed up with the main core and baked with it. In other cases, the main core is made in two parts and the insert core pasted to one part and baked with the assembled core; or the insert core and two-part main core can be made separately and pasted together after baking. (A. 26.)

Insert Die. A small die containing a portion or all of the impression of a forging, which is fastened in a master block for use in a forging unit.

Insertion Process. A method of making match-plate patterns which depends on cutting in the plate an opening corresponding to the base of the pattern and fixing the pattern into this opening with a low melting point alloy. For this purpose a circumferential groove is cut in the opening in the plate and a groove to match in the base of the pattern. The groove is filled by pouring low melting point alloy through a system of holes in the edge of the plate. (S. 29.)

Insoluble Anode. In *electrodeposition*, an *anode* that does not go into solution during the *electrolytic process*. (A. 27.)

Inspissate. To thicken by heating or evaporation.

Insulated Cooling. A method of controlling the cooling rate of a heated mass, e.g. steel, by covering it with inert insulating material, e.g. ashes.

Insulating Pads and Sleeves. As opposed to *chills*, insulating material, such as gypsum, diatomaceous earth, etc., used to lower the rate of solidification. As sleeves on open risers, they are used to keep the metal liquid, thus increasing the feeding efficiency. (A. 26.)

Insulating Refractories. Highly porous refractories to reduce heat absorption and radiation. Manufactured from diatomaceous earth or from clay mixings containing wood dust or other carbonaceous material which is burnt out in the kiln. The hot face insulating bricks or light weight firebricks are manufactured from more refractory mixings of clay and combustible matter and are burnt at a higher temperature.

Insulation. The prevention of the flow of an electrical current or the retarding of the flow of heat. To this end the conductor is surrounded by a suitable non-conducting medium.

In Tandem. (*In Train.*) An arrangement of stands in a rolling mill, one after another, so that the piece being rolled can travel in one direction through a number of stands.

Integrating Pole Figure Goniometer. This device permits of rotating a specimen of electrical sheet in an X-ray beam in such a way that the arrangement of the small crystallites which make up the metal can be determined from measurements of the diffracted beam, by means of an X-ray spectrogoniometer. This method of evaluation utilizes the fact that the arrangement of the crystallites in a metal, i.e. the preferred orientation or texture of the metal, influences many of its physical properties. From measurements of the preferred orientation of the transformer core material, the core losses and consequently the efficiency of the transformer can be accurately predicted. (E. 69.)

Integrating Photometer. The purpose of the instrument is to eliminate the personal factor in the estimation of the porosity of a casting from the appearance of an X-ray film. A beam of parallel light from an electric bulb is passed through the X-ray film down the neck of a large round-bottomed glass flask, coated internally with white lacquer and externally with black. A photronic cell fitted to the side of the flask measures the amount of light reaching the interior of the flask. As the percentage porosity of the casting influences the degree of blackening of the X-ray film, it can be determined from a knowledge of the amount of light absorbed in passing through the film to the flask. (S. 5.)

Intensifier. (*a*) For X-rays, a substance placed in, on, or under a photographic emulsion or a fluorescent screen, or used in photographic development, to make the effects of X-rays more conspicuous. (*b*) (See BORON).

Intensifying Factor. For X-ray *intensifiers*. The ratio between the exposure when no intensifier is used, and the exposure, for the same effect, when the intensifier is used provided that all other conditions remain unaltered. (A. 27.)

Intensifying Screen. In X-ray spectrographs, a separately mounted *intensifier*. (A. 27.)

Intensity. In X-rays, the flux of energy per unit of time and per unit of cross-section perpendicular to the direction of propagation.

Intensity of Magnetization. The magnetic moment per cubic cm. of a magnetized body having uniform magnetization throughout.

Interannealed Wire. Wire which has been drawn to an intermediate stage, annealed and then finally drawn to the required size.

Intercept Method. A method for *grain count*, in which the number of grains and fractions of grains along a line of known length on two axes at right angles to each other are counted. By the *Planimetric* method for grain count, the number of grains and fractions of grains within a definite area are counted. (A. 28.)

Intercommunicating Porosity. That type of porosity in a sintered compact in which the pores are connected so that a fluid may pass from one to the other completely through the compact. (G. 30.)

Intercrystalline Corrosion. (*Intergranular Corrosion.*) (*Weld Decay.*) A defect occurring in chromium nickel austenitic steels when submitted to certain types of chemical attack after heating within the range 500° to 800° C. At this temperature, the carbon is precipitated at the grain boundaries as chromium carbide, thus impoverishing the chromium content of the austenite adjacent to the boundaries and rendering them susceptible to corrosion. In welding, the material near the weld is heated in this range of temperature. For such zones, or in steel otherwise heated in this range, corrosion may produce complete disintegration of the steel at the crystal boundaries. The defect may be prevented by adding to the steel a carbide-forming element such as titanium or niobium which acts as a stabilizer. It is added in an amount sufficient to form a stable carbide and thus prevent the carbon from combining with the chromium. The alternative to adding the carbide-forming element is to maintain the carbon content of the steel at a very low level, e.g. $< 0{\cdot}03\%$. Corrosion resistant steels to which such carbide-forming elements have been added are referred to as *welding quality* or, less frequently, as *decay proof* steels.

Intercrystalline Corrosion Test. (See HATFIELD INTERCRYSTALLINE CORROSION TEST.)

Intercrystalline Failure. Failure taking place along the crystal boundaries.

Intercrystalline Fracture. Fracture taking place along the grain boundaries.

Interdendritic Attack. A type of electrochemical corrosion that sometimes occurs in "as cast" alloys or alloys that have had very little working. The attack progresses preferentially through areas around the dendrites, and dendritic arms, as a result of composition (*coring*) gradients. (A. 27.)

Interface. (*a*) The surface of separation of two phases. (*b*) The contact between a metal coating and the basis metal.

Interference Microscope. An instrument, which is particularly useful in the examination of surface topography, employing a birefringent element which produces interference fringes in the eyepiece of the microscope. These are bent by lack of flatness in the object under examination. The spacing of the fringe is adjustable and their lack of straightness, and thus any lack of flatness of the object, may be measured by a micrometer eyepiece. A wide range of normal microscope objectives may be used and a variety of fields, and magnifications therefore, covered. The instrument is portable and may be placed on large workpieces which require examination. Alternatively, small workpieces may be placed on the microscope stage. (R. 15.)

Interferometer. An instrument for the measurement of the wave-length of light.

Intergranular Corrosion. (See INTERCRYSTALLINE CORROSION.)

Intergranular Cracking. Cracking which takes place along the crystal boundaries and not through the crystals themselves.

Intergranular Penetration. The penetration of foreign substances along the grain boundaries of a metal.

Interlamination Resistance. This term is applied to the electrical resistance measured in the direction perpendicular to the plane of lamination in a stack of laminations. It indicates the effectiveness of the surface oxides and/or other coatings on the laminations in reducing the interlamination losses.

Interlocking Particles. Mechanical intertwining of particles. (G. 30.)

Interlocking Porosity. A system of intercommunicating voids in a sintered article; synonymous with *intercommunicating porosity*. (G. 30.)

Intermediate Annealing. An annealing treatment given to wrought materials before fabrication to final gauge and final *thermal* treatment. (A. 27.)

Intermediate Constituent. (*Intermetallic Compound.*) A constituent of alloys that is formed when atoms of two metals combine in certain proportions to form crystals with a different structure from that of either of the metals. The proportions of the two kinds of atoms may be indicated by formulae, e.g. CuZn.

Intermediate Cooler. (See CINDER NOTCH.)

Intermetallic Compound. (See INTERMEDIATE CONSTITUENT.)

Intermittent Weld. A joint consisting of a series of welds with spaces arranged alternately at prearranged and usually regular intervals.

Internal Chill. (See INVERSE CHILL.)

Internal Friction. The capacity of a solid to dissipate applied mechanical energy in the form of heat. (See DAMPING.)

Internal Oxidation. (*Subscale Formation.*) The precipitation of one or more oxides of alloying elements beneath the external surface of an alloy as a result of oxygen diffusing into the alloy from an external source.

Internal Shrinkage. A void or network of voids within a casting caused by improper feeding of that section during solidification.

Internal Soundness. A term referring to the condition of the steel as regards absence of defects, such as pipe, segregation, or non-uniformity of composition.

Internal Standard Line. In *spectrographic analysis*, a line within the spectrum of the material being analysed and due to a known amount of an element present in, or added to, that material. In practice, the intensity of the radiation producing the analysis line is compared with that producing the internal standard line, in order to minimize errors due to the effect of uncontrolled variables.

Internal Stress. Residual stress existing within a metal part due to the differential effects of heating, cooling or working, or to the mechanical structure of the metal, e.g. a coiled spring, or to constitutional changes in the metal itself. The most dangerous internal stresses are those due to quenching or rapid changes in temperature, which include contraction stresses due to cooling, particular precautions being necessary when the part is massive. In all such cases the greatest danger occurs at the time of, or shortly after, the imposition of the stress, after which, in the absence of oxidation, there is, in general, a tendency towards the neutralizing of stresses and a reduction in the danger. Given the necessity for introducing dangerous stresses, the safest plan is to reduce to a very minimum the time during which they can cause cracking, and heat treat or otherwise stress relieve the part without delay. Internal stresses can be measured by X-ray analysis which offers a non-destructive test, but detects elastic stresses only in a thin surface layer, or they may be measured by a destructive, mechanical method in which the specimen is bored out, cut or slit and the dimension changes determined by the use of a strain gauge from which the original internal stress can be calculated.

International Ampere. The direct current, which when passed through an aqueous solution of silver nitrate, deposits silver at the rate of 0·001118 gram per second.

International Ångström. A unit very nearly equal to the *Ångström* unit (10^{-8} cm.) but defined as being such that the red cadmium line at 15° C. and 760 mm. pressure would have a wavelength of 6438·4696 I.A. It is the unit adopted by the International Union of Solar Research for the measurement of the wave-lengths of light and X-rays.

International Ohm. The resistance offered to direct current at the temperature of melting ice by a column of mercury 14·4521 g. in mass of uniform cross-sectional area and 106·3 cm. in length.

International Volt. The *electromotive force* between the terminals of a conductor having a resistance of one *international ohm* through which a current of one *international ampere* is flowing.

Interpass Temperature. In a multiple-pass weld, the lowest temperature of the deposited weld metal before the next pass is started. (A. 37.)

Interplanar Distance. In crystals, the perpendicular distance between the nearest equivalent planes of a family; usually written d. the indices of the planes may be written as a subscript; for example, d_{100}. (A. 27.)

Interrupted Ageing. The ageing of an alloy at two or more temperatures by steps, and cooling to room temperature after each step. Compare with PROGRESSIVE AGEING. (A. 27.)

Interrupted Pour. Lack of union between parts of a casting. (I. 14.)

Interrupted Quenching. (*Time Quenching.*) This treatment is based on the rapid cooling of the work to a selected temperature by quenching in hot salt. Its effectiveness depends on one of the properties of molten salt not widely recognized until fairly recently—namely its cooling power at temperatures above 177° C. There are three main types of interrupted quenching: (*a*) *Cyclic Annealing*, which produces a soft and easily controlled structure with a very short time cycle. This method requires the highest temperature in the quench. (*b*) *Austempering*. This provides for medium hardness combined with ductility and toughness and good control of distortion. It requires medium temperatures in the bath. (*c*) *Martempering*. This process requires lowest temperatures in the quenching bath and gives high hardness equal to oil quenching with greatly reduced distortion and practically no residual stress. (A. 4.)

Inter-Service Metallurgical Research Council. (See Appendix V.)

Interstitial Solid Solution. A solid solution in which the atoms of the alloying element lie between, or in the interstices of, the atoms of the primary or solvent metal.

In Train. (See IN TANDEM.)

Intracrystalline Failures. Fractures across the grains in metal. (A. 27.)

Intrinsic Coercive Force. (See COERCIVE FORCE.)

Intrinsic Induction. (See INDUCTION, INTRINSIC.)

Intrinsic Induction Curve. (See INDUCTION CURVE, INTRINSIC.)

Introscope. (See BOROSCOPE.)

Invariant. Possessing no *degrees of freedom*.

Inverse Annealing. A *heat treatment*, analogous to *precipitation hardening*, applied to cast iron usually to increase its hardness and strength. (A. 28.)

Inverse Chill. (*Inverted Chill.*) (*Reverse Chill.*) The condition in a *grey iron* casting in which the interior is mottled or white, while the outer sections are grey. (I. 14.)

Inverse Cooling Curve. (See INVERSE RATE CURVE.)

Inverse Rate Curve. A curve produced by plotting the time in seconds required to cool or heat an alloy through a certain number of degrees of temperature against the actual temperature itself. Small deviations from the normal cooling or heating rate are shown up much more clearly by this method than by the normal time-temperature *cooling curves*.

Inverse Segregation. (*Negative Segregation.*) A concentration of alloy-rich material of lower melting point in the purer region of higher melting point which first solidifies; caused by the interdendritic flow of this alloy-rich liquid for which the following explanations have been offered:

(1) pressure on the liquid due to contraction of the shell;
(2) pressure on the liquid due to the growth of the dendrites;
(3) formation of long columnar crystals favoured by a steep temperature gradient and a long solidification interval in the alloy; and
(4) pressure resulting from the liberation of gas from supersaturated liquid.

Inversion. (*a*) The change occurring when a steel passes through the critical range on heating or cooling, passing for example, from the alpha to the gamma state. (*b*) A symmetry operation by

which each point of a structure is replaced by a point at the same distance from a fixed point (the inversion centre) but in the opposite direction therefrom. (See also SYMMETRY OPERATION.) (*c*) Molecular rearrangement in a crystalline material as from quartz to cristobalite in silica.

Inversion Casting. (*a*) A process of casting in which the metal is fed through a bottom feeder, the mould being inverted after pouring. (*b*) A process in which the mould is directly attached to the electric furnace in which the metal is melted in a reducing atmosphere so that no slag is formed. On inverting the furnace, the metal runs into the mould. There are no heavy feeders, and oxidation is prevented. Ordinary oil-bound foundry sands can be used but the surface of the castings is somewhat coarser than that attained by conventional practice.

Inverted Chill. (See INVERSE CHILL.)

Inverted Extrusion. (See EXTRUSION, INDIRECT.)

Investing. The process of pouring the *investment compound* into the flask surrounding the pattern to form the mould, in *precision casting.*

Investment. (See INVESTMENT COMPOUND.)

Investment Casting. (See LOST WAX PROCESS.)

Investment Compound. The term is often abbreviated simply to *investment,* which is the flowable mixture of a graded refractory filler, a binder and a liquid vehicle which when poured around the patterns conforms to their shape and subsequently sets hard to form the *investment mould.*

Investment Mould. The refractory mould used in *precision moulding.*

Investment Precoat. An extremely fine *investment* coating applied as a thin slurry directly to the surface of the pattern to reproduce maximum surface smoothness. The coating is surrounded by a coarser, cheaper, and more permeable investment to form the mould. (A. 26.)

Investment X Process. An *investment* process in which the wax pattern assembly is first spray-coated or dip-coated in the usual manner, and is then provided with a multiplicity of superimposed dip coatings, so that a shell of refractory materials of substantial thickness is formed. After formation of the shell, the wax is removed by immersion in trichlorethylene vapour, and the mould is then completed by packing the shell in a canister with dry refractory material. (M. 50e.)

Involute. Having incurved edges.

Inwalls. The tapering walls enclosing that part of the *blast furnace* extending upwards from the *bosh* to the *hopper.*

Io. Chemical symbol for *ionium.*

Iodide Process. (See VAN ARKEL PROCESS.)

Iodine. (*I.*) *Atomic weight* 126·91. A non-metallic element. It is practically insoluble in water, but readily soluble in, e.g. alcohol and ether. Iodine's many uses include that of an analytical reagent, as it forms a characteristic blue colour with starch.

Iodine Method. A residue method for the estimation of oxides in steel. It consists in dissolving a sample of drillings in a solution of iodine, filtering, igniting, and weighing the insoluble residue. The ignited residue is examined for silica, oxides of iron, manganese and aluminium, etc. (R. 39.)

Iodine Number. The number of grams of iodine absorbed by 100 grams of fat or oil. It is a measure of the amount of unsaturated acids present in fats and oils.

Ionic Concentration. The number of *ions* of a substance in a given volume, such as gram-ions per litre.

Ionic Crystal. A crystal where electron transfer results in some *atoms* having residual positive charges while others have residual negative electrical charges. Found in compounds of strongly electronegative and electropositive elements, for example, sodium chloride. (A. 27.)

Ionium. (*Io.*) A radioactive element. *Atomic weight* 230. A disintegration product from *uranium* minerals.

Ionization. (*Electrolytic Dissociation.*) The subdivision of the molecules of a substance into *ions* when dissolved in water or other suitable solvent.

Ionization Method. Any method of X-ray or crystal analysis that depends on measuring the electrical conductivity of a gas exposed to the diffracted X-rays. (A. 27.)

Ions. *Atoms* or radicals carrying a charge of positive or negative electricity in excess of the charges normally associated with the electrically neutral atom or radical, and therefore capable of conducting electric current.

I.O.W. *Institute of Welding.*

I.P.M. Abbreviation for *inches penetration per month.*

I.P.T. Institute of Petroleum Technologists.

I.P.T. Thermometers. Thermometers calibrated to the standards laid down by the Institute of Petroleum Technologists.

I.P.Y. Abbreviation for *inches penetration per year.*

Ir. Chemical symbol for *iridium.*

I.R.A.M. Instituto Argentino de Racionalizacion de materiales, i.e. The Argentine Institute of Standards.

Irco 66 "XX". A manganese-iron phosphate coating for iron and steel.

Irco-izing. A process which involves immersing the cleaned iron or steel articles in a concentrated solution of zinc dihydrogen phosphate, for 5 to 30 minutes at about 85° C. The 5-minute period is used when the finish is to serve as a paint base, and the 30-minute period is used when the coating is to be oiled. The iron replaces the hydrogen and a coating of zinc and iron phosphates is formed on the surface. (L. 48.)

I.R.E. Institute of Radio Engineers.

Iridescence. The play of prismatic colours on the surface of a mineral.

Iridium. (*Ir.*) *Atomic weight* 192·2. *Melting point* about 2443° C. *Specific gravity* 22·5. A hard brittle white metal resembling steel and malleable at a red heat. It is added to platinum for increased hardness. Such alloys are hard and corrosion resistant and are used for such purposes as pen points, hypodermic needles and standard weights. It is claimed that the use of iridium 192 in radiographic work permits more efficient inspection technique and that as iridium 192 emits gamma rays of less energy than cobalt 60, less lead shielding is required and handling is simplified.

Iridosmine. A naturally occurring alloy of *iridium* and *osmium.*

Irised. (See TARNISHING.)

Irite. A mineral consisting of a mixture of *iridosmine,* and *chromite.*

I-Rite Pyrometer. This instrument depends upon the fact that the intensity of the light rays, emitted by a hot body, increases as the temperature rises, and an attempt is made to judge the temperature of a given hot body by adjusting the intensity of the rays from a standard lamp, passing through a red filter, to the same intensity as the rays from the hot body.

Iron. (*Fe.*) Iron exists in three forms: *alpha iron, gamma iron,* and *delta iron. Atomic weight* 55·85. *Specific gravity* at 20° C. 7·87. *Melting point* 1535° C. Specific electrical resistivity 9·8 microhms per cm. cube. It is the basic metal in *steel* and *cast iron* and the most widely used of all metals. Iron is usually produced in the *blast furnace* from *iron ore,* the crude material being known as *pig iron.*

Iron-Iron Carbide Diagram. This diagram (Fig. 7), in which temperatures are plotted vertically and carbon contents horizontally, represents the equilibrium conditions over the whole range of carbon steels and cast irons. The line ABCD, known as the *liquidus,* represents the beginning of solidification on cooling and the end of melting on heating, i.e. at temperatures above this line the alloys are in the molten condition. The line AHJEF, known as the *solidus,* represents the beginning of melting on heating and the end of solidification on cooling; below this line all alloys are completely solid. It will be noted that, with increasing carbon contents, the melting point is progressively depressed until with 4·3% of carbon the alloy melts at 1130° C. as compared with 1535° C. for pure iron. The phases and duplex microconstituents, e.g. *ledeburite* and *pearlite,* stable under certain conditions of temperature and composition within the various fields, are indicated in the diagram as follows: Within the area AHB, the alloy exists as *delta iron* plus liquid; within AHN, between 1535° and 1405° C., it exists as delta iron; the region HJN represents *delta* plus *gamma* iron, whilst within the region BCEJ, i.e. between the liquidus and the solidus, the alloy is partly solid and partly molten and consists of gamma iron, i.e. *austenite,* plus liquid. The region DCF consists of cementite (Fe_3C) plus liquid, and NJESG consists wholly of gamma iron, i.e. austenite. GMO marks the boundary for non-magnetic *alpha iron* formerly known as *beta iron,* whilst MOSP contains a mixture of alpha iron (*ferrite*) and gamma iron (austenite). The field ESKF consists of austenite plus ledeburite and cementite plus ledeburite as indicated, whilst below the line PSK are found the constituents ferrite plus pearlite, cementite plus pearlite, and cementite plus pearlite plus transformed ledeburite, as indicated. It is on this diagram that the heat treatment of steel is based. On progressively heating *hypo-eutectoid steels* through the *transformation range,* the conversion of pearlite into austenite is followed by the gradual solution of ferrite which reaches completion at the A_3 point. In *hyper-eutectoid steels,* cementite progressively dissolves in the austenite. *Eutectoid steels* transform completely to austenite at a fixed temperature. The addition of alloying elements may profoundly modify the transformation ranges. The limits of the transformation range, may be determined by measuring the temperatures at which evolution of heat (*recalescence*) and absorption (*decalescence*) occurs. Other methods of determination include the measurement

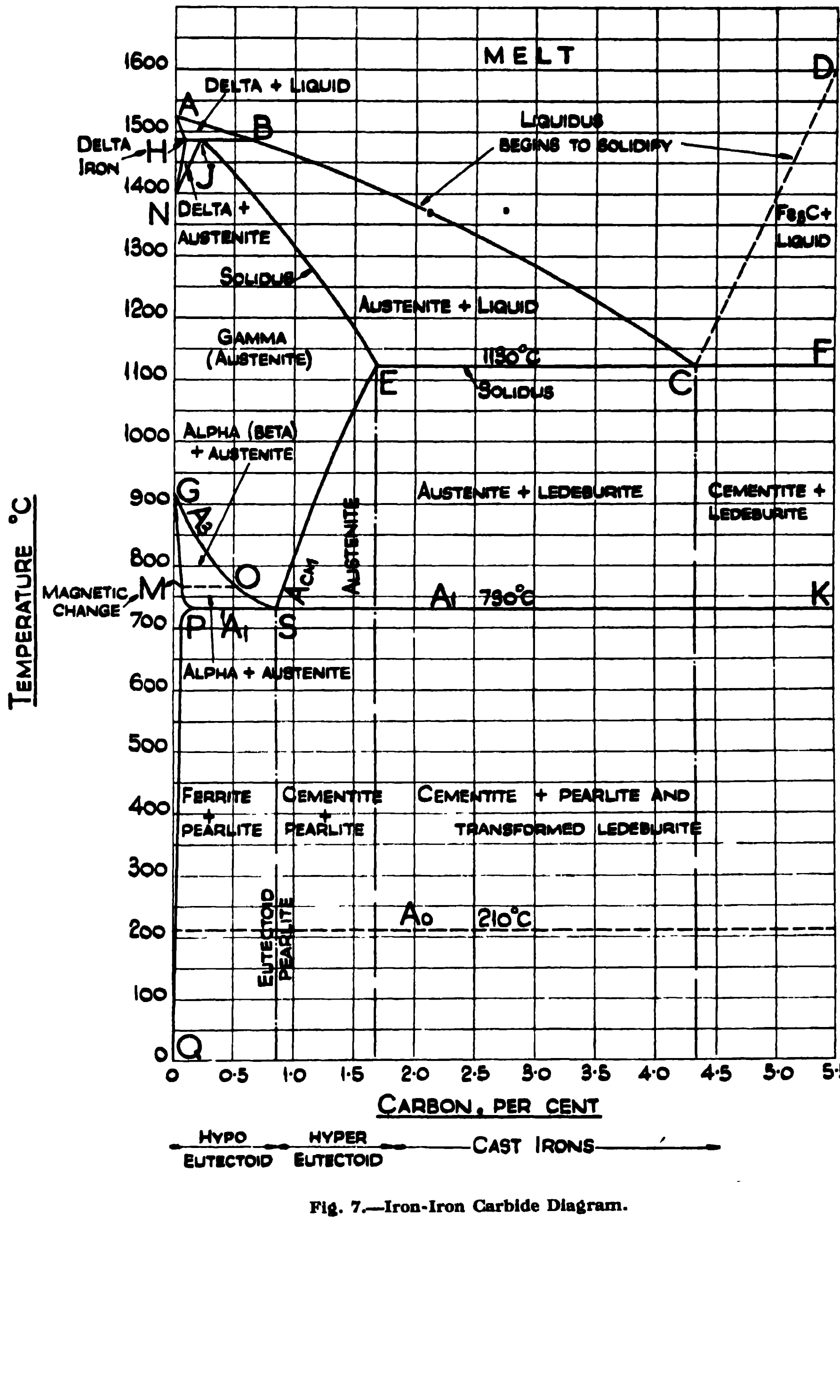

Fig. 7.—Iron-Iron Carbide Diagram.

of the change in length with temperature or the rapid quenching from various temperatures in order to inhibit transformation with subsequent examination of the specimens, for example, either metallographically, or by X-ray crystallography, or by hardness measurements. (See also TRANSFORMATION RANGE and TRANSFORMATION TEMPERATURE.)

Iron Constantan Couple. A thermocouple consisting of a positive wire of iron and a negative wire of *constantan*. It is recommended for use in reducing atmospheres at temperatures up to about 850° C.

Iron Froth. A spongy type of *haematite*.

Iron Glance. A name sometimes applied to specular iron ore (*haematite*).

Iron Notch. The opening or *tap hole* for the removal of the molten *pig iron* from the *blast furnace*. It is situated at the front of the furnace near the bottom of the hearth and is stopped with clay.

Iron Ore. The principal ores of iron are *haematite* (Fe_2O_3); *magnetic iron* (Fe_3O_4); *limonite* ($2Fe_2O_3.3H_2O$); *chalybite* ($FeCO_3$) and *chrome iron ore*. The chief producing countries are the U.S.A., U.S.S.R., France, the United Kingdom and Sweden, but of these only France and Sweden are large ore exporters. Prior to *smelting*, certain ores require special treatment. For example, carbonate ores are calcined, fine ores must be sintered or briquetted to allow the passage of the gases in the blast furnace, whilst for the same reason, dense ores must be broken up to render them more porous. (O. 18.)

Iron Oxide. Three oxides of iron are known: iron monoxide (FeO), *ferrous oxide*; *iron sesquioxide* (Fe_2O_3), *ferric oxide*; magnetic oxide of iron (Fe_3O_4), *ferrosoferric oxide*.

Iron-Powder Process. A process for flame cutting stainless steel, similar to the *oxy-arc* process, but having iron powder metered into the oxygen stream to aid in fluxing refractory oxides forming on the molten steel.

Iron Protoxide. (FeO.) *Ferrous oxide*.

Iron Pyrites. (See PYRITES.)

Iron-Rich Powder Process. (See POWDER CUTTING PROCESSES.)

Iron Sand. (See ISERINE.)

Iron Sesquioxide. Ferric oxide (Fe_2O_3.)

Iron Sick. A term sometimes applied to bolts that have become so rusted that they permit leakage.

Ironstone. A general term for *iron ore*.

Iron Vitriol. (*Copperas, Green Vitriol.*) Ferrous sulphate. $FeSO_4.7H_2O$.

Ironing. A process in which the wall thickness of a metal cup is reduced while the internal diameter is kept constant. This is achieved by forcing it through a die with a closely fitting internal punch. (H. 57.)

Irregular Kerf. Deep fluting, notching, or other irregularities on a cut edge, resulting for example, in gas cutting, from the inaccurate adjustment of the blowpipe or cutting speed.

Irreversible Reaction. A reaction which takes place in one direction only, and therefore proceeds to completion, as for example, the burning of magnesium in oxygen to oxide.

IRSIA. *Institut pour l'Encouragement de la Recherche scientifique dans l'Industrie et l'Agriculture.*

IRSID. Institut de Recherches de la Siderurgie. Saint Germaine-en-Laye, Paris.

Iserine. (*Iron Sand.*) A black sand which consists mainly of magnetic iron ore but also contains a considerable amount of titanium.

I.S. Met. (See INTER-SERVICE METALLURGICAL RESEARCH COUNCIL.)

I.S.O. International Organization for Standards. 32 Route de Malagnon, Geneva, Switzerland.

Isobar. A curve relating quantities measured at the same pressure.

Isobares. Elements having the same atomic weight but different atomic numbers and hence different chemical properties.

Isobaric. An adjective used to indicate a change taking place at constant pressure.

Isochore. A graph showing two variables in an isometric change; a line on a thermodynamic diagram showing how the pressure of a constant volume of gas varies with the temperature.

Isochronous Governor. An instrument fitted to an engine with the object of maintaining exactly constant speed. (B. 45.)

Isohydric. Having the same *pH* values, or concentration of hydrogen ions.

Isoma Hardness Tester. An instrument for measuring Vickers values on small, round, and flat metal parts, foil, tinplate, glass, plastics, etc. It has an automatic weight-selecting device for applying dead weight loads from 50 to 1000 g. The built-in optical measuring system is said to permit measuring impressions accurately to within 0·000004 in. (A. 31.)

Isometric. Concerning crystals, cubic. (A. 27.)

Isomorphism. The name given to the phenomenon whereby two or more minerals which are closely similar in their chemical constitution, crystallize in the same system of symmetry, and develop very similar forms.

Isomorphous. Phases with crystal structures of the same type. (A. 26.)

Isopac. A proprietary insulating paste. (See SELECTIVE CARBURIZING.)

Isosklers. Lines connecting points of equal hardness.

Isothermal Annealing. Heating the steel to above the upper *critical temperature* and cooling rapidly to a predetermined temperature and holding there for the time to complete transformation. The holding temperature selected coincides with the upper portion of the *isothermal transformation* diagram where transformation to pearlite occurs and the steel should be cooled at a sufficiently rapid rate to prevent transformation at higher temperatures. More uniform microstructures are obtained with this type of annealing which provides accurate control of the temperature.

Isothermal Reaction. A reaction taking place at constant temperature, as in *austempering*.

Isothermal Transformation. The process of transforming the *austenite* in steel to *ferrite*, or a ferrite-carbide aggregate, at any constant temperature within the *transformation range*.

Isothermal Transformation Curve. (*I.T. Curve.*) (See TIME TEMPERATURE TRANSFORMATION CURVE.)

Isotope. (See RADIOISOTOPE.)

Isotropic. Having the same properties in all directions.

I.S.W.G. Abbreviation for *Imperial Standard Wire Gauge.*

Itabiryte. A metamorphosed sedimentary iron ore found in Brazil, and averaging 40% to 50% iron.

I.T. Curve. Abbreviation for *Isothermal Transformation Curve.*

I.T.E. *Institute of Traffic Engineers.*

Ixiolite. A niobo-tantalate of iron and manganese containing a small amount of tin.

Izett Steel. A steel, developed for use in boilers and for boiler rivets, etc., characterized by its resistance to strain age embrittlement. The steel contained about 0·09% C, 0·06% Si and about 0·05% Al. (A. 34.)

Izod Impact Test. (*Cantilever Beam Test.*) The test piece of 10 mm. square in section is notched transversely by a V-cutter, to a depth of 2 mm. and an angle of 45°. The radius at the bottom of the notch is ¼ mm. The piece is fixed vertically in the vice of the machine by the lower end with the notch at the level of the face of the vice. When the pendulum of the machine is released, it swings freely, and a knife edge carried in the *tup* of the machine strikes the place at a distance of 22 mm. above the notch, on the same side as the notch. The angle of swing of the pendulum beyond the vertical after breaking the test piece is indicated by a pointer which should have been previously set to zero. From the amount by which the angle falls short of the angle to which the pendulum would have swung if there had been no test piece, the amount of energy absorbed in breaking the test piece is known, and is indicated by the pointer in ft. lb. Three tests are usually done on one piece, the notches being placed on different sides of the piece. The height of fall of the centre of mass of the pendulum is 2½ ft. and the capacity of the machine 150 ft. lb. or 120 ft. lb., the distance from the pivot to the striking edge being 4 ft. The striking velocity (when using the full capacity of the machine) is 13·6 ft./second. The British Standard round test piece, which is used in certain cases as an alternative to the square test piece, has a diameter of 0·45 in. The notch has an included angle of 45°, root radius of ¼ mm., and a depth of 0·13 in. (B. 102.)

J

J. (*a*) Symbol for *gram equivalent weight.* (*b*) Symbol for the *mechanical equivalent of heat.*

Jack Chain. An open joint link chain, for applications not requiring strength.

Jack Star. A piece of hard metal for use in a tumbling barrel, used for cleaning castings. (A. 26.)

Jacket. The term as used in the foundry refers to a wooden or metal form or box, which is slipped on to a mould to support the sides during pouring.

Jackmanizing. A method of case carburizing. The details of the process have not been published, but a deep case is produced.

Jacquet Continuous Ingot Casting Process. A method of casting steel in which multiple moulds, arranged horizontally, are connected directly to the ladle. It is claimed that the method affords an increase in the cooling surfaces, gives protection against oxidation, and that the increased rate of cooling gives a uniform crystalline structure and limits the segregation. (S. 126.)

Jacquet Method. (*a*) (See ELECTROLYTIC POLISHING). (*b*) (See JOSSERAND AND JACQUET PROCESS).

Jaggars Microsclerometer. An early type of hardness testing instrument in which a diamond point of constant

dimensions was rotated on a mineral specimen under uniform rate of rotation and standard weight to a standard depth. The number of rotations of the point which was used as a measure of the duration of the abrasion, varied as the resistance of the mineral to abrasion by a diamond. (J. 6.)

Jamb. Usually an upright structural member forming the side of an opening in a furnace wall. (A. 26.)

James Spun-Cast Process. A process for the production of spun-cast liners and piston ring pots, in which the moulds are maintained at a temperature between 300° and 350° C., with the object of producing castings, free from chill, which can be machined in the as-cast condition. (M. 25.)

JAN. Joint Army-Navy Specification. (U.S.A.)

Jannin Method. A method of testing wear, which consists in measuring the depth of an impression produced by friction under constant load. (N. 13.)

Japan. A varnish coating often used as a finish for steel articles and as a protection from corrosion. The varnish coating is baked after application.

Japanese Industrial Reports. A series of reports published by the *British Intelligence Objectives Sub-Committee*, and distributed through the Technical Information and Documents Unit, 5–11 Regent Street, London, S.W.1.

Jar Ramming. The packing of the sand in the mould by raising and dropping upon a table, the sand, pattern and *flask*, the weight of the sand itself being the ramming medium. *Jolt squeezers, jarring machines*, and *jolt rammers* are moulding machines which use this principle.

Jarring Forehearth. (See DECHESNE JARRING FOREHEARTH.)

Jarring Machine. (See JAR RAMMING.)

Jarring of Ingots. A method proposed for producing sound ingots is that of jarring or shaking the moulds while the metal is being poured and thereafter while the steel is still in the molten condition. (M. 14.)

Jaw Contact. A clamping device used in resistance welding to hold the parts to be welded and to conduct the current.

Jean Rïst Technique. (See RÏST TECHNIQUE.)

Jenkin's Bend Test. An alternating bend test through 180° performed by means of a small portable machine having a constant radius of bend.

Jenolite Rust-Removing Process. A process for removing rust and scale from steel, and, at the same time, imparting a protective phosphated surface to the metal which, moreover, provides a key for subsequent painting. Jenolite, the proprietary liquid compound used in the process, consists essentially of zinc phosphate. If the articles to be treated are small they are first degreased and then dipped into a tank containing a solution of one volume of the liquid diluted with two volumes of water maintained at a temperature of 55° C., whilst in the case of larger objects, the Jenolite is applied by brush. (E. 58.)

Jernkontoret Standards. A series of ten hardened steel fractures, ranging from No. 1 which is relatively coarse to No. 10 which is relatively fine. (See FRACTURE TEST.)

Jernkontoret's Slag Inclusions Scale. This scale, which is standard in Sweden, consists of a series of micrographs, designed to show different typical fields of view, and arranged in groups according to the form and distribution of the inclusions and numbered according to their quantity. In the practical application, the appearance of the specimen under the microscope is compared with the micrographs in the scale. (R. 28.)

Jernkontoret's Standard Hardness Blocks. These are standard specimens of accurately determined hardness, specially prepared for the periodic checking of the Rockwell C machine. The blocks are claimed to be accurate to within ± 0·2 Rockwell C units covering the hardness values of 65, 60, 55, and 50 Rockwell C respectively. (H. 80.)

Jernstedt's Process. (See PERIODIC REVERSE CURRENT PROCESS.)

Jessop Cladding Method. In this method, two slabs of stainless steel with a separating compound between them (the composition of the compound is not stated) are inserted between two mild steel slabs. Steel bars are tack-welded along the edges of the stainless steel and the latter is sealed within the mild steel slabs by machine welding all round the edges. This composite block is then rolled out under great pressure, which welds each stainless steel sheet to its mild steel backing. The welded edges are afterwards cut away and the pair of clad sheets is separated. (S. 117.)

Jet Tapping. A method of tapping open hearth furnaces by means of an explosive charge.

Jetal. A method for producing a corrosion resistant coating on ferrous articles. It involves immersing the work from 5 to 60 minutes depending on the concentration of the salts. The bath consists of a strong caustic solution containing a

strongly oxidizing agent. The reaction is one of oxidizing the iron to a black oxide. (L. 48.)

Jetweld. A shielded-arc welding electrode with a coating containing a powdered metal constituent. The electrode is designed to facilitate fast and easy operation in flat and near-flat positions with A.C. or D.C. welding. The powdered metal present in the electrode coating is claimed to make the welds crack-resistant and to provide impact-resistance properties not found in conventional electrodes.

Jevon's Tear Length Test. (See TEAR LENGTH TEST.)

Jib. The projecting part of a crane from the end of which the lifting chain or gear is suspended.

Jig. (*a*) An appliance used in machining operations for grinding tools in the production of interchangeable parts. (*b*) An appliance used for holding parts together during welding.

Jobbing Mills. (See ROLLING MILLS.)

Jockey. (See RIDER.)

Joggling. The production of a bend or shoulder in a section of sheet or strip metal in order that it may over-ride the contacting section and so form a lap joint.

Johansson Hardness Test. An indentation method, to determine the hardness of wire specimens. A hardened steel cylinder is pressed on to the specimen, the long axes of the cylinder and specimen being at right angles. The width of the elliptical projection of the indentation is measured in a direction parallel and at right angles to the long axis of the wire, the values being expressed as functions of the indenting pressure. Formulae for the construction of diagrams expressing the hardness of specimens tested in this way are derived. The method is suggested as being of value in the study of *ageing* processes. (J. 17.)

Johnson Brinell Machine. A hardness testing instrument in which the loads available are 500, 750, and 3000 kg. (H. 9.)

Johnson's Theory. An expression based on the second law of thermodynamics, expressed as follows: The proportion of any given quantity of heat which can be utilized for conversion into work depends on the temperatures at which the heat is applied and discharged. Johnson considered that for every blast furnace there is a certain critical temperature only above which can certain necessary operations of the process be carried out. Given the existence of such a temperature, the heat available for performing these operations is the portion left after deducting the amount necessary to raise the products of combustion to that temperature. (E. 84.)

Johnston's Apparent Elastic Limit. The point above the *elastic limit* where the *strain* with respect to the *stress* is increasing at a rate 50% faster than it increases for any stress below the elastic limit. (C. 5.)

Joints. (*a*) The junction of crystalline grains. (*b*) A union of two or more parts. (*c*) A *welded joint* is one where union is effected by welding. (*d*) A *mechanical joint* is one where union is effected by mechanical means, e.g. by screws or rivets, and welding is not employed. (*e*) A *composite joint* is one where welding is one of two or more means used for making the connection. (*f*) The *parting line* in a *sand mould*.

Jolt Rammers. (See JAR RAMMING.)

Jolt Squeezers. (See JAR RAMMING.)

Jolting of Ingots. (See JARRING OF INGOTS.)

Jominy Test. In this test a standard test piece, 1 in. diam. × 4 in. long, is heated to a predetermined temperature, rapidly transferred to a jig fixture, and quenched under standard conditions, by a jet of water impinging on one end. When the specimen is sufficiently cool, hardness determinations are made longitudinally along the specimen from the quenched end, following suitable preparation; the diagram relating hardness to distance from the quenched end of the specimen is known as a *hardenability curve*. (J. 22a.)

Josserand and Jacquet Process. A method for the production of bright steel bars in which the bars are rolled to within one hundredth of an inch of the finished dimension and are then straightened, cut, finished cut and finally planished on special machines.

Joule. A unit of energy equal to 10^7 *ergs*, derived from the practical system of electrical units. It may be defined as the energy dissipated in one second by a current of one *ampere* flowing across a potential difference of one *volt*.

Joule Effect. (*a*) (See MAGNETOSTRICTION). (*b*) The heating effect caused by an electric current flowing through a resistance. (See JOULE'S LAWS (*c*).)

Joule, James Prescott. (1818–89.) An English physicist, chiefly remembered for his contributions to the study of heat and electricity.

Joule-Kelvin. (See JOULE-THOMSON EFFECT.)

Joule-Thomson (Joule-Kelvin) Effect. The slight fall in temperature which occurs when a gas is allowed to expand without doing external work. The effect is due to energy absorbed in over-

coming the cohesion of the molecules of the gas.

Joule's Laws. (*a*) The intrinsic energy of a given mass of gas is a function of temperature alone; it is independent of the pressure and volume of the gas. (*b*) The molecular heat of a solid compound is equal to the sum of the atomic heats of its component elements in the solid state. (*c*) The heat produced by a current I passing through a conductor of resistance R for a time t is proportional to I^2 Rt.

Journal. That part of a rotary shaft or spindle which is in contact with, and supported by, a bearing. (See ROLLING MILLS.)

Jovignot Fluid Pressure Cupping Test. The standard form of this test, which records the cupping coefficient and stress strain curve of relatively thin sheet, is carried out on an adapted *Guillery machine*. The standard punch of the Guillery machine, which is pressed into the test piece to be deformed by means of oil pressure, is replaced by a piston and a leather washer. The test piece is clamped down tightly to form the fourth wall of a small upper oil cylinder, the fluid pressure acting directly upon the underside of the specimen to form a cup when the pressure of the lower oil cylinder is increased. (G. 37.)

Judd Lewis Comparator. An instrument for the identification of lines in a spectrum. It consists of a two-way microscope, by which objects placed beneath the two objectives may be viewed through one eyepiece. The stage is an open frame divided into sections, each of which will carry a spectrum plate. The plates can be moved parallel to either their major or minor axes, so that an unknown spectrum may be compared with a standard spectrum on which several lines are marked with the symbols of the elements which they represent. (B. 15.)

Jump. (See PINCH.)

Jump Butt Weld. A butt weld where a part of small cross-section is welded to a part of larger cross-section.

Jump Join. A butt joint made by *jumping up* the ends of two pieces before joining them together.

Jump Mill. A mill used for roughing light bars.

Jump Roll. A plain roll, with collars on each end, used in rolling flats.

Jumper. The steel bit of a compressed air rock drill.

Jumper Steel. *Jumper* steel is specified as having a carbon content of 0·60% to 0·65%, manganese 0·20% to 0·40%, and not more than 0·035% sulphur and phosphorus.

Jumping. Striking a bar on end in order to increase its diameter.

Jumping Up. A forging operation in which the original section is forged down or *up-ended* into an appreciably wider section.

Junction. In welding, a surface of the fusion zone bordering the zone of thermal disturbance. (B. 105.)

Junction Crack. A crack in the junction between weld and base metal.

Junghans-Rossi Process. A process for the continuous casting of both ferrous and non-ferrous metals. Liquid metal from a holding furnace or insulated ladle enters a water-cooled mould the axis of which is vertical and the solidified casting descends continuously from the bottom of this. The moving casting is cut into suitable lengths by a saw or flame. The essential feature of the process is a reciprocating motion applied to the mould. This reduces friction and improves the cooling efficiency. (See also CONTINUOUS METAL CAST PROCESS.)

Junker Mould. A water-cooled copper-faced mould. (J. 30.)

K

K. (*a*) Symbol for *potassium*, from the Latin *kalium*. (*b*) Abbreviation for *Kelvin degrees*. (*c*) The letter that designates the series of characteristic X-rays having, for each element, the shortest wave-lengths. Greek letters and Arabic subscripts are used to distinguish the lines of the K-series; for example, copper $K\alpha_1$, molybdenum $K\beta$.

K Factor. In the U.S.A. this represents the tensile strength in lb./sq. in. divided by the Brinell hardness number.

Kael-Lundin Welding Process. The method employs a three-phase A.C. welding current and electrodes with twin core wires. (B. 97.)

Kahlbaum Iron. Iron of more than 99 975% purity produced in Germany. In the United Kingdom it has been superseded by iron of even higher purity produced in this country.

Kaliphite. A mixture of *limonite*, with oxides of manganese, and silicates of zinc and lime.

Kalium. (See POTASSIUM.)

Kalling-Domnarfvet Process. A process for the desulphurization of hot metal in which powdered burnt lime is used as the desulphurizing agent. The hot metal from the blast furnace is tapped into a ladle and transferred to a rotary furnace which is in a horizontal position, and can be rotated at various speeds. An addition of finely ground burnt lime,

about 2%, and 0·5% of coke breeze is made, and the furnace, sealed to the atmosphere, is set in rotary motion. The sulphur in the hot metal is absorbed by the lime. The time of treatment is normally 30 minutes. (F. 25.)

Kalling's Process. An early method for the reduction of iron ores, in which electricity was used for heating the charge. A rotary kiln was charged with a mixture of ore and carbon material and heated between two-disc-formed electrodes. The method has been abandoned. (I. 30.)

Kalling's Solution. An etching reagent for developing the microstructure of chromium steels with more than 5% of chromium. It contains copper chloride 5 gm., hydrochloric acid 100 ml., alcohol 100 ml., and water 100 ml. (K. 3.)

Kangro Process. An electrolytic method for the production of iron powder for melting in the electric furnace. (M. 93.)

Kanigen Process. A plating process which consists essentially of immersion of the part to be coated in an agitated solution of nickel chloride and sodium hypophosphite, held at 100° C. The process depends on catalytic reduction of nickel compounds by the hypophosphite on the surface of certain metals; the coating deposited is a nickel-phosphorus alloy. As deposited, it has normally a hardness of 550 to 650 Vickers; by variations in plating technique and/or heat treatment, hardnesses as low as 400 or as high as 900 Vickers can be produced. It is used for the deposition of hard wear-resistant coatings on industrial components such as valves or crankshafts. The essential features are covered by two U.S. Government-owned patents, Nos. 2,532,283, and 2,532,284. (C. 8.)

Kanner's Special. A quality of tin plate carrying a minimum coating of 1·40 lb. of tin per basis box.

Kaolin. The purest form of *china clay* consisting of a silicate of aluminium. The name is derived from Kaolin, a hill in China from which the Chinese obtained supplies of clay for the production of chinaware.

Kaolinite. A definite mineral form of *kaolin* corresponding to the chemical formula $Al_2O_3.2SiO_2.2H_2O$. It has a melting point of 1785° C.

Kappa Carbide. A carbide of iron ($Fe_{23}C_6$) in which all or part of the iron may be replaced by chromium, molybdenum and/or tungsten, $(Fe,Cr,Mo,W)_{23}C_6$.

Karat. (See CARAT.)

Kathabar Method. A method of drying the blast used in cupolas, blast furnaces and converters. It employs lithium chloride for absorbing the moisture.

Kayseler Deep Drawing Test. Specimens of sheet material are prepared in a wedge-shape; on drawing the wedge through a flat draw-plate, the material is submitted to varying degrees of deformation. Erichsen cupping tests are then made at various positions on the deformed specimen, and in this way information is obtained regarding the effect of different degrees of previous deformation on the results obtained in the cupping test. (K. 10.)

Kayser Hardness Test. A method for determining the true hardness of metals at high temperatures. The specimen, in the form of a cone with an angle of 120°, rests on an anvil, and is submitted to a load of 35 kg. for a period of 10 days. The anvil, cone and plunger are enclosed in a small electric resistance furnace, which can be maintained at any desired temperature up to 1150° C. The hardness number is derived as in the Brinell test, namely, the area of flattened surface on the cone in sq. mm. is divided into the load in kg. (M. 119.)

Keebush. A plastic constructional material which will withstand the action of both sulphuric acid, of up to 50% concentration, and hydrochloric acid. It is used for the construction of *pickling tanks*.

Keel's Method. A method for the low-temperature stress-relieving of joints *in situ*, the joint being made by back-hand welding. Stress-relieving is carried out by passing the flame slowly along the joints so as to cover three times the width of the weld. (H. 64.)

Keeper. (*a*) The man in charge of a *blast furnace*. (*b*) A piece of soft iron placed across the poles of a horse-shoe magnet when it is not in use.

Keep's Shrinkage Test. In this test a bar 12 in. long and ½ in. section is cast between the jaws of a cast iron yoke, the shrinkage on cooling being measured by means of a graduated steel taper gauge.

Kelcaloy. (See KELLOG ELECTRIC FUSION PROCESS.)

Keller Furnace. An early type of electric furnace which resembles the *Heroult* save for the fact that the electrode supports are not attached to the furnace, and, therefore, at the end of the heat the electrodes have to be lifted out of the furnace before the molten steel can be poured. (K. 11.)

Keller's Spark Test. (See SPARK TESTING.)

Kellog Electric Fusion Process. A method of producing composite slabs of carbon steel clad with alloy steel by

fusing carbon steel electrodes and tubular electrodes through which the alloying materials (e.g. ferrochromium) are supplied, to the surface of the carbon steel under the protection of molten flux. The process has been developed under the trade name of *Pluramelt*, whilst the rolled composite products are called *Kelcaloy*. This process has also been used for the manufacture of a composite ferritic/austenitic component for joining together austenitic and ferritic steam-pipe. (H. 74.)

Kellog Electric Hot-Top Process. This process involves supplying heat to the top of the metal teemed in an ingot mould while the teemed metal is covered by a protecting blanket of flux. This promotes solidification of the teemed metal, with a minimum formation of defects due to shrinkage, in a manner to increase the yield of sound ingot metal. The heat is supplied to the top of the metal teemed in a manner and in quantity controlled to provide a reservoir, of gradually diminishing size, of highly heated molten metal which feeds to the solidifying metal beneath as volume changes due to solidification take place, and which persists until solidification of the teemed metal is substantially completed. Essentially, the installation consists of a source of power and a liquid-cooled, non-consumable, non-contaminating electrode. Heat is generated by the discharge of electric current from the end of the electrode, submerged in a flux, without detrimentally affecting the required properties and characteristics of the teemed metal. (K. 43.)

Kelvin. A name sometimes used for kilowatt-hours.

Kelvin, Lord (William Thomson). (1824–1907.) A British physicist, who is remembered chiefly for his numerous contributions to electricity and magnetism.

Kelvin (K) Degree. Temperature measured from *absolute zero*. (See also KELVIN TEMPERATURE SCALE.)

Kelvin Effect. (See THOMSON EFFECT.)

Kelvin & Hughes Mk. 5 Crack Detector. An instrument for the ultrasonic inspection of forgings and castings. It is capable of detecting small defects by using the 2½ mc/s. beam from separate 2 cm. diameter transmitter and receiver crystal probes, or alternatively using the less sensitive frequencies of 1¼ or ⅝ mc/s. and appropriate crystals, where material grain size makes penetration difficult. The unit will detect favourably aligned defects at distances at 2 in. to 20 ft. from the probes. The greater depths of penetration are achieved by using mosaic crystal probes, working at the lower frequencies producing 9 narrow beams. A combined trans-receiver probe although having a restricted maximum depth due to the wide angle beam, is capable of detecting defects situated a few mm. below the surface. (M. 35.)

Kelvin Temperature Scale. The *absolute temperature* scale in which the temperature measure is based on the average kinetic energy per molecule of a perfect gas. The zero of the Kelvin scale is $-273{\cdot}18°$ C. The temperature scale adopted by the International Bureau of Weights and Measures is that of the constant volume hydrogen gas thermometer. The magnitude of the degree in both these scales is defined as $\frac{1}{100}$ the difference between the temperature of melting ice and that of boiling water at 760 mm. pressure.

Kenmore Process. A method for the manufacture of plated-steel wire in which copper or nickel is deposited electrolytically on to a steel core which is then drawn to the specified gauge.

Kentron Microhardness Tester. An optical microhardness tester, using an elongated pyramid, and working with a direct load from 1 to 1000 g. (K. 19.)

Kerf. (*a*) The *cut* made by a saw. (*b*) The gap formed by the burning or melting out of metal during *cutting* by *thermal* or chemical means.

Kerosene. A refined distillate of petroleum, often called *coal oil*, and distilled in the temperature range of 150° to 300° C.

Keshian Reagent. A solution for deep etching. It consists of 500 ml. HCl, 70 ml. H_2SO_4, 180 ml. water.

Kessler Mill. An intermittent acting mill in which the strip passes round a large roll and is reduced by the action of small rolls. The large roll is idle and the strip is pulled through the machine by a *tension reel*. (K. 12.)

Key. (*a*) A piece of bar fitting into recesses of two machine parts required to be held together. (*b*) A wedge used to fasten dies into the forging equipment, e.g. into the hammer tup or the anvil block.

Keyhole Notch. (See CHARPY TEST.)

Keyhole Specimen. An impact specimen provided with a *keyhole notch*.

Kibble. A large bucket used in shaft-sinking in mines.

Kidney Ore. A variety of *haematite* occurring in reniform masses from which it takes its name.

Kieselguhr. (See INFUSORIAL EARTH.)

Kil. (*Kilo.*) A prefix signifying one thousand times, e.g. *kilometre, kilogram.*

Killed Bessemer Process. In this process, molten iron is added at the end of the blow so that the carbon in the iron removes the oxygen from the steel as a gas. Ferro-manganese and ferrosilicon, and finally 3 lb. of aluminium are added per ton of steel in the ladle to ensure complete deoxidation. (P. 41.)

Killed Spirits of Salts. A solution of zinc chloride, $ZnCl_2$, made by dissolving zinc in hydrochloric acid, and used in *soldering*.

Killed Steel. (*Fully Killed, Solid Steel, Piping Steel.*) Steel that has been completely *deoxidized* by the addition of manganese, silicon, and sometimes aluminium, before casting so that there is practically no evolution of gas during solidification, and sound ingots are obtained. The shrinkage cavity or pipe is limited to the upper portion of the ingot or in the *feeder head* with which such ingots are usually provided.

Killed Wire. Wire which has been mechanically processed in order to eliminate its tendency to spring.

Killing. (*a*) See *Deoxidation*. (*b*) The prevention of *kinks* and *stretcher strains* in strip on further manipulation by the application of a small degree of cold work (e.g. *skin passing*) when it is in the finally heat treated condition.

Kilo. (See Kil.)

Kilocycle. Measure of frequency of electric discharge or alternating current. One thousand cycles.

Kilogram. (*Kilogramme.*) One thousand grams. Continental unit of mass and weight. 2·2046 lb.

Kilometre. One thousand metres. The Continental unit of distance, 1094 yards, or 0·6214 mile.

Kilowatt. (*kW.*) A unit of electrical power equal to one thousand watts (approximately 1·34 horse-power).

Kilowatt-Hour. (*kWh.*) A unit of electrical energy equal to 1000 watt hours.

Kinematic Viscosity. The ratio of viscosity to density.

Kinetic Energy. The energy which a body possesses by virtue of its motion.

Kinetic Theory of Gases. The mathematical explanation of the behaviour of gases on the assumption that gases consist of *molecules* which are in ceaseless motion in space, the *kinetic energy* of the molecules depending upon the temperature of the gas. The molecules are considered to be perfectly elastic particles which collide with each other and with the walls of the containing vessel. The pressure exerted by a gas on the walls of the vessel is due to the collisions of the molecules with it.

King Portable Hardness Tester. An instrument designed to operate on the same principles as the *Brinell hardness tester*, but of lighter construction. It weighs 26 lb., and puts an actual load of either 500 or 3000 kg. on a 10 mm. ball. (W. 14.)

Kink Bands. These were first described by Orowan, in 1942, after he observed that, when single-crystal wires of cadmium were compressed between the hands, they sometimes yielded suddenly with the formation of distinct kinks. Since then, bands have been found to form in many other single crystal metals under various forms of stressing. It has been suggested that they are sharply bounded regions of the crystal within which the orientation is continuously changing because of lattice curvature. (M. 112.)

Kinking. (*Flattening.*) The sudden yielding, with the simultaneous appearance of *stretcher strain markings*, which occurs on distorting annealed or hot rolled sheet.

Kinzel Inclusion Count Method. In this method, a number of representative fields of longitudinal sections of 2 in. round and square bars, are photographed at a magnification of 50 diameters. The negatives are then enlarged by projection and the lengths of the inclusions measured. All inclusions down to a size of 0·005 mm. are counted and their results expressed as the number of inclusions of a given size per square millimetre and as a total length figure, i.e. the sum of the lengths of all of the inclusions per square millimetre, as if they were placed end to end. (K. 24.)

Kinzel Test. A measure of ductility employing a notched slow bend specimen. The specimen is a simple beam, 3 in. wide, 8 in. long, of plate thickness, with 0·01 in. radius, 45° notch, 0·05 in. deep. It is tested statically at 1 in. per minute ram motion. It may comprise a longitudinal *weld bead*. (K. 23.)

kip. A term sometimes used in the U.S.A. to denote a unit of 1000 lb. (453·59 kg.), e.g. 100 kips/sq. in. = 100,000 lb./sq. in.

Kirkendall Effect. The diffusion of solid metals. It is associated with the displacement of diffusion interface due to unequal diffusion rates of the constituents, together with the rejection of excess vacancies by the lattice, thus forming micro pores where the unequal rates of diffusion have concentrated vacancies. (H. 46.)

Kirov Method. A process of melting high alloy steels, in which steel is melted under a small quantity (1% to 2%) of semi-acid slag in a basic electric-arc furnace. During melting, 1·5% to

2% of lime is added to form a slag. Oxidation to eliminate phosphorus should be complete in 15 to 20 mins. When the carbon has been reduced to 0·10% to 0·08%, the slag is almost completely removed and ore is added to reduce the carbon content to 0·02%. After the boil (40 to 50 min.) 75% of the slag is removed. For refining, the bath is treated with aluminium, ferro-silicon, crushed fireclay and manganese. After deoxidation and the formation of a thin fluxing layer, preheated ferro-chrome is added in portions as required. The metal is stirred after the ferro-chrome has melted, the slag being treated with 5% ferro-silicon, after which the current is switched off and any further alloying additions are made. Finally, the current is switched on for 3 to 4 min. The whole refining period lasts 90 to 95 min. (N. 15.)

Kirsch Test. An early type of hardness test based on the load required to press into the specimen a steel punch of 5·0 mm. diameter to a depth of 0·01 cm.

Kish. (*a*) Solid graphite which has separated from molten iron during the process of melting. (*b*) The carbon or graphite which separates out in plates from *cast iron* during solidification. (*c*) Dross on the surface of molten lead. (*d*) (See SKULL).

Kisser. A patch of scale remaining on a steel sheet after pickling. It is the result of two sheets having remained in close contact during the descaling operation.

Kjeldahl Process. A process used in chemical analysis for the quantitative determination of nitrogen.

Kjellberg Process. (See KAEL-LUNDIN WELDING PROCESS.)

Kjellin Furnace. An early type of induction furnace in which the metal lay in a circular trough, the ring of metal forming a closed iron circuit through which a secondary current or currents were induced by means of a primary high-voltage current passing through specially wound coils. The primary was level with the bath of steel and was wound round one leg of the transformer which was built up of laminated plates. This type of furnace, however, merely provided a melting medium and did not allow of any refining. (B. 23.)

Kjerrman Inclusion Count. A method for the determination of slag inclusions in iron and steel in which the results are expressed as the number of inclusions per sq. mm. The magnification used is about 200 and all inclusions are counted down to those 0·002 mm. in size. (K. 29.)

Klaproth, M. H. (1743–1817.) A German chemist who discovered uranium and zirconium in 1789, isolated titanium in 1795, and tellurium in 1798.

Klatte System of Rolling Chains. A bar of special shape is employed, which is rolled down to size, submitted to a punching process, pressed into the form of a rough chain, and then completed by further operations. (K. 31.)

Klaus. (See CLAUS.)

Kling Type Ladle. A refractory lined iron vessel for receiving the iron from the blast furnace. It is spherical in shape and has an opening at the top to receive the iron. It acts both as *ladle* and *mixer*.

Klöckner-Humboldt-Deutz Process. A composite casting process in which the coating metal is introduced into the steel bushing in the form of turnings, powder or small lumps, together with the necessary flux. The bushing is then mounted in a centrifugal machine in which it is held by means of two end covers. The bushing is rotated and at the same time is heated from the outside. After the coating alloy in the bushing has been melted and has bonded to the steel, the bushing can be cooled and then removed from the machine. As cooling is usually effected with water in order to produce rapid solidification and thereby ensure a fine grain size and absence of segregation, only non-quench hardening steel can be used for the bushings, as otherwise, subsequent machining would be rendered impossible. This means that only steels with a carbon content not exceeding about 0·3% are suitable. (S.31.)

Knife-Line Attack. A form of intergranular corrosion which appears in a narrow band adjacent to a weld in steels of the austenitic 18/8 type. This attack occurs under specific conditions and has been observed in fuming nitric acid and also in boiling 65% nitric acid. (H. 69.)

Knobbled Iron. An old name for *wrought iron*.

Knobbler. (See SHINGLER.)

Knobbling. (See SHINGLING.)

Knockout. (*a*) In *powder metallurgy*, the term relates to the ejection of a compact from the die cavity. (*b*) In the foundry, it relates to the area where the moulds are taken to remove the casting from the sand. (*c*) A mechanism for removing work from the die after completion of forming operations such as deep drawing, forging or stamping.

Knockout Pins. Small diameter pins: (*a*) affixed to die casting or permanent mould dies that eject the casting upon opening the die; (*b*) affixed to patterns

for removing cured moulds in the *shell-moulding* process.

Knockout Punch. A punch for ejecting compacts from a cavity.

Knoop Hardness Indenter. A diamond indenting tool of special shape used for the determination of microhardness. The special feature of this indenter is that it is ground to a pyramidal form that produces a diamond shape (rhomb) indentation having long and short diagonals of approximately the ratio of 7 to 1. The pyramid shape employed has an included longitudinal angle of 172° 30′ and includes a transverse angle of 130°. It permits hardness determinations of extremely thin metal-plated surfaces, exceptionally hard and brittle materials, shallow carburized or nitrided surfaces. The long diagonal is but little affected by elastic recovery when the load is removed. (See also TUKON TESTER.)

Knotter. A machine for tying the end of the top or bottom of a coil spring about itself, thus fastening the ends.

Knuckling. Joining lengths of wire by bending over the ends.

Knurling. The formation of a series of ridges upon the periphery of a circular part, usually with the object of increasing the firmness with which it can be gripped by the hand.

KO_3. Chemical formula for potassium oxide.

Koft-Karl. The Indian name for inlaid metal work, usually consisting of gold wire on steel.

Koldflo Extrusion Process. A process for cold shaping under compression by a combination of forward and backward displacement, *coining, expanding* and *ironing*.

Koldweld Process. A proprietary name for the method of cold-pressure welding without the use of heat or electricity, developed by the General Electric Co. Ltd. in the United Kingdom (see COLD WELDING), and made available in the U.S.A. by the Koldweld Corporation of New York. (D. 46.)

Kolene Process. A method of cleaning the surface of cast iron in preparation for enamelling or brazing. The casting is placed in a bath of molten salt at 260° C. and a current of 6 volt is passed with the work as the cathode, in order to reduce scale or rust on the surface. The polarity is then reversed so as to oxidize impurities such as sulphur, phosphorus and graphite in the bare metal surface. Finally, the current is again reversed so as to remove the iron oxide formed during the previous cycle. (S. 62.)

Kollagram. (See KOLLAGRAPH.)

Kollagraph. An apparatus for the measurement and recording of the jointing capacity of soldering systems, the autographic records obtained being known as *kollagrams*. (E. 1.)

Kolmetal. A corrosion-resistant coating for the protection of cast iron sections in contaminated salt-water. The coating is a mixture of finely pulverized aluminium in a plastic vehicle, the aluminium comprising 85% by volume. It is applied by brush or spray. The surface must be completely clean before application, with no trace of oxidation or scale.

Konimeter. An instrument for the determination of dust in the atmosphere. It consists essentially of a spring-operated pump by means of which 5 ml. of air are drawn at high velocity (about 100 metres per second) through a narrow jet (about 0·05 cm. diameter) so as to impinge normally on a glass slide held at a distance of about 0·05 to 0·1 cm. from the jet orifice. The surface of the slide is previously prepared by coating with a thin film of glycerine jelly or vaseline to make the particles adhere, and as many as 30 samples can be taken on one slide. A microscope is often incorporated in the instrument to enable the samples to be examined as soon as they are collected. (B. 128.)

Konode. (See CONODE.)

Kostron Hardness Tester. A multi-hardness tester of the Brinell type for investigating the relationship between hardness and time of loading. It is capable of making eighteen impressions either simultaneously or over a period of time which can be set to vary within the range 4 to 1040 minutes. A specimen at high temperature can be tested in this machine, and it is, therefore, possible to obtain data on the changes in hardness in relation to time as a specimen cools. (K. 44.)

Kourbatoff's Reagent. An etchant for steel; it consists of 7 parts of a solution containing 20% methyl alcohol, 20% ethyl alcohol, 20% iso-amyl alcohol and 10% butyl alcohol added to 3 parts of a solution of 4% nitric acid in acetic anhydride. This etchant colours sorbite and troostite leaving the other constituents unaffected.

Kr. Chemical symbol for *Krypton.*

Kraft. Unbleached wrapping paper.

Krang Process. A method of producing malleable iron in which the charge, usually consisting of equal quantities of pig iron and steel scrap, is melted in a cupola and tapped into a ladle. About a sixth of the ladle contents is then transferred to a side blown converter where most of the silicon, carbon and

manganese is removed, the blown metal then being returned to the ladle. The mixed metal is then transferred to an electric arc furnace from which it is finally tapped.

Krause Mill. A cold reducing mill for the production of sheet. The material is held by a gripper at one end which keeps the material under tension during the working stroke of the mill. At the beginning of the working stroke the rolls are in a position slightly behind the previously rolled material; the rolls are backed up by cam plates which are held in the mill housing. The rolls are turned by friction between the material and the cam plates; the drive is applied to move the housing and cam plates forward. During the working stroke, the sloping surfaces of the cam plates bear on the top of the upper roll and the bottom of the lower roll so that the material is squeezed between the rolls and is moved forward at the same time. Very heavy reductions per pass can be made in this mill. (B. 62.)

Kroll Process. A method of extracting titanium or zirconium by reduction of the tetrachloride with molten magnesium in an atmosphere of helium. (M. 109.)

Krouse Plate-Fatigue Testing Machine. In operating this machine, one end of the specimen is gripped in a vice, and the other end is reciprocated vertically by means of a connecting rod and eccentric crank mechanism. A dead weight, required to produce the desired stress in the critical section, is applied to the pin, in the clamp, with the connecting rod disconnected and swung out of position. The deflection is noted on the dial indicator, for both upward and downward loads of the desired amount. The connecting rod is then coupled, and the eccentric cam adjusted to provide the same deflections of the dial indicator. For each revolution of the motor a completely reversed cycle of end deflection of the specimen is applied. (D. 41.)

Krupp Krankheit. (See TEMPER BRITTLENESS.)

Krupp-Renn Process. A method of treating low-grade iron ores in which finely divided iron ore is mixed with coke breeze and fed into the upper end of a slowly-revolving kiln which is fitted with an annular barrier or stop-ring at the lower, and firing end, this causing the depth of charge beneath the flame to be considerably increased. By this means the reducing conditions inside the kiln are so adjusted that the ore is reduced to pellets which grow in size as they pass down the kiln and are finally discharged with the semi-solid slag to a cooling belt. From here, the issuing mixture of pellets and slag is fed to a series of mills, screens and magnetic separators which serve to separate the pellets from the slag, the slag being discarded and the intermediate middlings returned for further treatment. The pellets are suitable for re-melting in the open-hearth or electric furnace, or they can be used to enrich blast-furnace burden. (I. 62.)

Krupp Solution Standard I.C. Test. (See HATFIELD I.C. TEST.)

Krupp Welding Process. (See AUSTENITIC WELDING.)

Kryptol. A mixture of carbon, graphite and carborundum. It is used as a resistant material and for heating-elements in electric furnaces.

Krypton. (*Kr.*) *Atomic weight* 83·80. An inert and very rare gas.

K Test Piece. A liquid shrinkage test for foundry purposes. After cooling, the casting is examined for external draws, then broken to reveal any internal shrinkage cavities. Tests may be 6 in. overall and 1 in. square in section.

Kulin and Cohen Instrument. An instrument developed at the Massachusetts Institute of Technology for determining the intensity of magnetization in a uniform and constant field of high intensity.

Kupfer-Panzerstahl. Steel bars around which copper is cast, the compound bar being afterwards drawn down to rod or wire, which possess high strength and corrosion resistance. (L. 13.)

Kusnezow Pendulum Sclerometer. A hardness testing instrument in which a pendulum is supported on the surface of the specimen by two hard steel points or balls which form the indenters. As the pendulum swings, the indenters penetrate into the surface of the specimen under test. In a brittle material, a crystalline powder is formed in the depressions thus made, whilst in a more plastic material, the test piece becomes cold worked, a new surface being produced under the indenters as the pendulum rocks to and fro. The more powder formed, or the more rapid the cold working, the sooner will the oscillations of the pendulum damp down. Therefore, the time taken for the specimen to bring the initial amplitude of vibration down to a predetermined value is taken as the hardness index. (K. 55a.)

kVA. = kilovolts × amperes. Used instead of *kilowatts* as a measure of power in alternating-current circuits.

kW. Abbreviation for *kilowatt.*

K-Weld. A process which uses inert-gas shielded-arc welding to apply the

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Plate VI.—Teeming electric steel from ladle into ingot moulds.

initial bead. The same process, metal-arc or any acceptable fusion welding method, may be used to complete the weld. (P. 39.)

kWh. Abbreviation for *kilowatt hour*.

K.W.I. Cupping Test. A test for ductility which employs a cylindrical tool, 40 mm. diam. with an edge radius of 5 mm., and has a projection 12 mm. diam. on the face. The test piece, 90 mm. square, has a central hole, reamered out to 12 mm. diam., with all burrs carefully removed from the edge. The test may be carried out in the *Guillery machine*, the projection in the centre of the tool face serving to centre the hole at the beginning of the test, which is continued until a crack appears at the edge of the hole. The diameter of the hole is then measured and the ductility is expressed as the percentage widening of the hole. (G. 37.)

kX. Abbreviation for Kilo-X-unit. Differs slightly from an ångström unit (10^{-8} cm.). (See X.)

Kyanite. A crystalline anhydrous aluminium silicate rock which, when calcined for use as *grog*, is usually known as *sillimanite*.

Kymograph. A device for the automatic recording of the phenomena under observation. It comprises a rotating drum and tracing is effected by a writing point.

Kyroscopy. A name proposed by Sauveur for that branch of metallography dealing with the effects produced in metals and alloys on cooling.

L

L. *Inductance, Self.*

La. Chemical symbol for *lanthanum*.

Labile. Unstable.

Labile Range. The range in which crystals form from a melt spontaneously, although if the melt is kept still it may be cooled for some distance into this range before crystallization begins, this phenomenon being known as *undercooling*. If, however, the melt is shaken, crystallization sets in as soon as the labile range is reached. (See also METASTABLE.)

Lack of Fusion. Incomplete union of the *weld metal* with the parent metal in a *fusion weld*.

Lack of Root Penetration. (See IMPERFECT ROOT PENETRATION.)

Lacquered Plate. Tinplate covered on one or both sides with lacquer for appearance or additional protection.

Ladle. A vessel for receiving the molten metal from the furnace. It consists of an outer shell of mild steel lined with firebricks. A hole in the bottom of the ladle is provided for the *nozzle*, which is a suitably shaped refractory with a central hole through which the molten steel flows from the ladle into the *ingot mould*. The upper end of the nozzle is shaped to receive the stopper head. The *stopper* assembly consists of a refractory *stopper head*, usually of plumbago bonded with clay, an iron *stopper rod*, the *stopper pin* and wedge, and *sleeve bricks*. The stopper pin is placed in the stopper head, the other end of the pin being inserted into the end of the stopper rod where it is held in place by the wedge. The rod is then covered with sleeve bricks, and all the joints, together with the hole in the end of the stopper head where the pin is inserted, are cemented up. The upper end of the stopper rod is attached to a *goose neck*, fitting over a vertical sliding bar attached to the outside of the ladle. This bar is provided with a lever by which means the stopper is raised or lowered, thus controlling the flow of molten metal through the nozzle. Since the stopper controls the flow of metal into the mould, shutting off the stream as each mould is filled, it must withstand both the action of hot steel and slag and remain in good shape throughout the pouring of the entire heat. A new stopper is prepared for each heat poured. (See Plate VI.)

Ladle Addition. The addition of alloying elements, in the form of metals or ferro-alloys, to the molten steel in the ladle.

Ladle Analysis. The term applied to the average chemical composition of a heat or blow of steel before it is poured into the ingot moulds. (See LADLE SAMPLING.) (S. 85.)

Ladle Chill. The freezing of molten steel in the *ladle*.

Ladle Sampling. The common practice in most steel melting operations of obtaining more than one ladle test sample from each heat or blow; often three or more are taken representing the first, middle and last portions of the heat or blow. Drillings taken from the first sample or middle sample are used in determining the *ladle analysis* because experience has shown that these locations most closely represent the chemical analysis of the entire heat or blow. The additional samples are used for survey of uniformity and for control purposes. (S. 85.)

Laffon Hardness Tester. (See AMSLER LAFFON HARDNESS TESTER.)

Lag. *Thermal hysteresis*. (See TRANSFORMATION RANGE.)

Lattice. (See SPACE LATTICE.)
Lattice Constants. The lengths of the sides of the unit cell in a *space lattice*, given in *ångström units*.
Lattice Energy. (See HEAT OF SOLUTION.)
Lattice Parameter. The distance between successive points in a space lattice measured in a direction parallel to one of the three principal axes. A space lattice has three parameters of which all may be different, all may be equal, or two may be equal.
Laue Method. For crystal analysis. A method using heterochromatic X-rays, a small fixed crystal and a plane screen, usually a photographic plate; the *Laue spot* is the image (of a pinhole or of the small crystal itself) characteristic of the resulting diffraction pattern. (A. 27.)
Laue Pattern. (See LAUE PHOTOGRAPH.)
Laue Photograph. (*Laue Pattern.*) A photograph made by the *Laue method*.
Laue Spot. (See LAUE METHOD.)
Launder. (*Lander.*) The channel down which the molten steel flows on tapping, from the *tapping* hole of the furnace to the *ladle*.
Lauth Mill. (See ROLLING MILLS.)
Lavite Process. A proprietary method of annealing wire in a molten *salt bath* of special design, which is heated by passing an electrical current through the bath.
Lavoisier, A. L. (1743–94.) A French scientist who is chiefly remembered in that he established the theory of combustion. Throughout his life his interests were divided between pure science and its application in the service of man, as for example, his investigations included methods of street lighting and experimental farming. (H. 23a.)
Law of Definite Proportions. This states that in every sample of any one compound substance, the proportions by weight of the constituent elements are constant.
Law of Octaves. It was first noted by J. A. R. Newlands, that when the elements were arranged in the ascending order of their atomic weights each eighth element was a "kind of repetition of the first". He provisionally termed this relationship, the law of octaves. However, the inaccuracy of the atomic weights at that time, about 1866, masked the truth of this finding and little attention was paid to it until the *Periodic Table* arranged by Mendeleeff had been accepted.
Lawrence Smith Method. A method used in chemical analysis for the determination of alkalis.
Lay. (*a*) The direction of the predominant surface pattern. For example, on a turned cylinder the lay is circumferential. A lapped surface, being produced by multimotion, has no predominant pattern, and thus has no lay. (*b*) The direction in which wires are bound into strands.
Lay Days. The time, in days, specified for the loading or unloading of cargo.
Layer. A stratum of the weld metal of a fusion weld consisting of one or more runs of metal side by side. The number of runs deposited depends on the cross-sectional area of the welds and the welding technique employed. (B. 105.)
Layer Line. In revolving-crystal and oscillating-crystal methods, a row of spots caused by families of planes equally inclined to the axis of rotation or oscillation. (See SIDE SPECTRUM, ZERO SPECTRUM.) (A. 27.)
Layer Method. A method for determining pouring rate and mould orientation in casting steel, and which gives a graphical representation of the regions in the mould which are critical with respect to *cold shuts*. The mould volumes in consecutive horizontal layers are calculated and plotted against the height of the mould. From this curve and from the pouring rate at bottom teeming, the rising speed is calculated for various layer volumes.
Layer Thickness Meter. A pocket-sized instrument for the measurement of non-ferrous layers on ferrous bases. It contains a shaped moving iron mounted at the neutral axis of a powerful permanent magnet. One end of the magnet is fitted with a spherical pole-piece of hardened steel which projects through the case of the instrument. When the spherical steel tip is placed on a ferrous plate, the magnetic flux distribution is disturbed and the moving iron takes up a new position of equilibrium. Because of the suppression of the spring, small non-magnetic layers placed between the steel tip and the base cause relatively large movements of the moving iron and the scale can be calibrated in the thickness of the non-magnetic layers. (I. 17.)
Layer Weld. (See MULTIPASS WELD.)
Layout. The transference of drawing or sketch dimensions to *templates* or *dies* for use in *sinking dies*. Also checking a *forging* or a *lead cast* to determine whether its dimensions are in accord with those given on the drawing or model.
Layout Board. A board upon which a *pattern* layout is made. (A. 26.)
L/B. Ratio of length to breadth.
l.c. (See LOWER CASE.)

L-D Process. (See LINZ-DONAWITZ PROCESS.)

Le Centre Technique des Industries de la Fonderie. (French *Technical Centre for the Foundry Industry.*) This Centre was formed in April 1949, under a Government ordinance and is financed by a compulsory levy on the whole industry and by charges for work done. The objects of the Centre are to promote technical progress in the foundry industry, particularly in respect to productivity and quality of product. A central research and testing laboratory has been established at Sevres and there are regional laboratories in a number of localities. The Centre provides a consultant service and a special library. Publications include *Fonderie* and *Journal d'Informations Techniques des Industries de la Fonderie.*

Le Chatelier Couple. A *thermocouple* employing a negative wire of pure platinum and a positive wire of 90% platinum and 10% rhodium.

Le Chatelier, Henry Louis, F.R.S. (1850-1936.) A French scientist who carried out many notable researches in the field of metallurgy and did much to advance the precise measurement of high temperatures.

Le Chatelier Pyrometer. An instrument employing a platinum, platinum-rhodium thermocouple, used for measuring temperatures within the range 300° to 1600° C.

Le Chatelier's Principle. If some stress is brought to bear upon a system in equilibrium, a change occurs, such that the equilibrium is displaced in a direction which tends to undo the effect of the stress.

Lea Lectromag. A production version of the gauge devised by *Lipson* for the measurement of the thickness of electrodeposited coatings. (R. 6a.)

Leaching. (*Lixiviation.*) The extraction of soluble metals from an ore by dissolving in a solvent which does not affect the *gangue*. The metal is subsequently precipitated from the solvent.

Leaching-Rate Test. A test designed to assess the value of anti-fouling compositions by measuring the rate of loss of toxic ingredients from a painted surface during immersion in sea water. In conducting the test, small glass panels coated with the anti-fouling compositions under test are stored in sea-water and transferred periodically into the leaching apparatus, where they are subjected to agitation (by bubbling) in a definite amount of sea-water for a standard time; the toxic substances leached into the water are then determined. (I. 79.)

Lead. (*Pb.*) *Atomic weight* 207·21. *Specific gravity* 11·34. *Melting point* 327·3° C. A grey metal, very soft and *malleable*. The clean surface shows a metallic lustre, which soon disappears on exposure to air; it is very resistant to corrosion. It is used as pipe for domestic water supply, sheet for roofing purposes, storage batteries, cable sheathing, ammunition, and for many purposes in chemical plant, where its corrosion resistance is increased still further by small additions of other metals, such as copper, nickel and tellurium. The addition of about 0·25% lead considerably improves the machinability of steel. The only effect of such addition on the normal tensile and Izod properties in either direction is a slight tendency to lower ductility and toughness values. Reduced fatigue resistance may also result, a tendency which increases with increase in the tensile strength of the steel. Notch sensitivity in fatigue is unaffected by lead addition. (W. 69.)

Lead. A term sometimes used for a conductor of electrical current.

Lead Bath. A bath of molten lead used for the heat treatment of steel (e.g. LEAD PATENTING).

Lead Cast. (*Lead Proof.*) A reproduction in lead, or lead alloy, of the die impression, of a forging. It is made by clamping the two dies together and pouring molten metal into the impression thus obtained.

Lead Coating. The practice of immersing chromium- or austenitic chromium-nickel corrosion resisting steel wire in a bath of molten lead prior to drawing operations for the purpose of lubrication. The lead coat is removed when drawing is completed. (Also known as *Lead Lubrication Process.*)

Lead Glance. (See GALENA.)

Lead Lubrication Process. (See LEAD COATING.

Lead Patenting. A *patenting* treatment in which cooling is commenced by quenching medium or high carbon steels of small section in a bath of molten lead in order to obtain a fine pearlitic structure.

Lead Printing. A method for the macrographic examination of the distribution of *lead* in steels. The surface of the steel is etched with a 10% solution of ammonium persulphate. Printing paper is immersed for 2 minutes in a 5% solution of caustic soda, dried between blotting paper and squeegeed on to the metal surface. After about 2 minutes the paper is removed, developed in a 5% sodium sulphide solution and rinsed.

Lead Proof. (See LEAD CAST.)

Lead Quench. (*a*) Quenching of the hot metal in molten lead in order to gain quenched and tempered properties in one step and thus avoid the *martensitic* condition, e.g. *austempering.* (*b*) (See LEAD PATENTING.)

Lead Sulphide Cell Radiation Pyrometer. A photo-conductive semiconductor having the property of undergoing an almost instantaneous resistance change when exposed to infra-red radiation. It is most sensitive to wave-lengths between 1μ and 2μ. One type of cell consists of a thin film of lead sulphide sublimed into an evacuated pyrex envelope containing a suitable tungsten and *Aquadag* electrode assembly. (H. 34.)

Lead-Tin Coating. An 85% lead–15% tin alloy can be electrolytically coated on to steel from a fluoborate bath, and the steel can be soldered without the use of acid fluxes. The coating is claimed to be practically free from porosity and to possess good corrosion resistance. Moreover, it acts as lubricant thus reducing wear on dies and forming rolls.

Leaded Steel. (See LEAD.)

Leader Pass. A term sometimes applied in rolling to the first forming pass after *cogging.*

Leafing. In powder metallurgy, the capacity to form groups consisting of 2 to 4 particles.

Leak Vibroscope. An instrument which detects leaks in water, oil, gas, steam and air lines by amplifying the sound produced by the escaping fluid. (V. 9.)

Leakers. A term applied in American foundries to iron castings which have failed to meet liquid or gas pressure tests.

Lean Ore. An ore containing a low metal content.

Leave. (See DRAFT.)

Lectro-Clad Process. (See BART PROCESS.)

Lectromelt Furnace. A three-phase current direct arc furnace.

Ledeburite. The *eutectic* of the *iron/iron carbide* system. It freezes at about 1130° C. and is composed of *austenite* and cementite containing about 4·3% carbon. During cooling, the austenite may transform to *ferrite* and *cementite.* It is typically found in cast iron. (See (Plate X(a).)

Leduc Effect. (*Righi-Leduc Effect.*) The temperature difference between two edges of a metal strip, heated at one end, when its plane is placed perpendicularly across a magnetic field.

Leeds Northrup Milliammeter Type Pyrometer. An optical pyrometer. To determine the temperature of a hot body the pyrometer is sighted on to it and the visible radiation from it is brought into focus by a lens in the same plane as the dip of a tungsten filament within the pyrometer between the eyepiece and the lens. By adjustment of the current flowing through the lamp filament, the intensity of the filament tip is adjusted to match that of the intensity of the hot body. The current required to produce this intensity in the filament is then read off from the milliammeter and the temperature determined from calibrated data.

Leeds Northrup Pyrometer. A roll surface temperature unit, which measures the temperature of a moving roll surface without touching the roll. The primary element works on the principle that a moving object carries with it a thin, closely adhering layer of air nearly the same temperature as the moving surface. Mounted $\frac{1}{32}$ in. from the surface is a measuring head, contoured to fit the roll. A continuous stream of air is sucked past the measuring element and thus heats it to virtually the same temperature as the roll surface. (I. 10.)

Leftward Welding. (See FORWARD WELDING.)

Leg. A *fusion face* of a *fillet weld.*

Lehigh Notch Bend Test. A test for the *ductility* and notch sensitivity of welded material. It employs a longitudinal notch bend specimen consisting of a plate 12 in. by 3 in. with a thickness of $\frac{1}{2}$ to $\frac{3}{4}$ in. In testing, a single weld bead is deposited on the centre line on one side of the test plate, the plate being notched at 2 points 4 in. apart. The notch has a depth of 0·080 in. and a radius of 1 mm., which enables the notch root surface to expose *weld metal,* heat affected zone, and *parent metal,* thus providing an opportunity for failure to originate in that area most sensitive to cracking. After notching, the specimen is tested by bending between 7 in. centres, using a constant rate of deflection equal to 3 in. per minute. (S. 145.)

Lehr Short-Time Fatigue Test. An endurance test which measures the power input required by a fatigue testing machine under various loads. A marked increase of power input is shown at a load which causes a stress which is not far from the endurance limit as determined by long.time tests. (E. 36.)

Leighton Buzzard Silver Sand. A white refractory *moulding sand.*

Leitz Dilatometer. This instrument works on the principle of differential

measurements between the unknown sample and a standard alloy of known expansion. The two specimens, ⅛ in. diam. by 2 in. long, rest side by side on quartz tubes closed at one end. They transmit their length changes through quartz rods to a plate, thence to a prism supported at three points, two of which are movable and one fixed. This movable prism guides a luminous point of light, from a low voltage lamp, on to a light sensitive film where the point describes a curve. Such a curve is then superimposed on to a graduated film, giving direct readings in mils per inch expansion as the ordinate, when plotted against temperature in degrees centigrade as the abscissa. (G. 21.)

Leitz Durimet. (See DURIMET.)

Lemon Spots. (See FLAKES.)

Length. Bar or wire cut to a specified length.

Length, British Units of. (See Appendix II.)

Length, Metric Units Of. (See Appendix II.)

Lennox Sand Drier. A non-rotary hot air drier for foundry sand. (F. 35.)

Leonard Effect. An effect produced by the gases in a congested part of the moulding sand, which is strongly heated by the metal but is not sufficiently permeable to allow the gases produced to escape to the exterior of the mould. The Leonard effect should not be confused with real shrinkage cavities.

Leopard Spots. Dull grey areas, usually circular in shape which occur on tinned steel sheets. The spots are detrimental to the appearance of the sheets, and appear to be caused by the flux adhering to the sheets being raised to excessive temperatures in the hot dip tinning operation. (R. 35.)

Lenticular. Lens shaped, i.e. having a double convex.

Lenz's Law. This states that the direction of an induced current is such that its magnetic field tends to oppose the change in strength of the magnetic field which is setting up the induced *e.m.f.*

Letters Patent. (See PATENTS.)

Letting Down. A term used in engineering for *tempering* a steel to the desired degree.

Level-Bubble Strain Gauge. A strain gauge which has a sensitivity of 7 millionths of an inch. A 5-second level-bubble is used as a measuring device; it is fastened to the moving leg of the instrument, and its level changes with strain along its gauge-length. (B. 121.)

Levelling. Flattening rolled metal sheet. (See ROLLER LEVELLING.)

Levelling Solution. The name given in electroplating, to an electrolyte to which certain additions have been made in order that it will deposit a surface having a greater smoothness than the original base.

Lever Type Machine. A machine in which mechanical or hydraulic leverage is employed, and which terminates in a weighing beam or steelyard. The poise or proportional weights on the beam may be manually or power operated and controlled. (B. 100.)

Levigation. The grinding of a substance in a liquid and the subsequent separation of fine powder from coarser material by suspension in liquid. (A. 27.)

Levitation Melting. A method of heating and melting metals by suspending them in space with an electromagnetic field. The field is generated by applying H.F. current to two co-axial coils connected in series opposition. (W. 76.)

Leydenfrost Phenomenon Phase. The phase occurring in the oil quenching of steel, during which the workpiece is enveloped in an atmosphere of oil vapour.

L.F.E.M. Laboratoire Federal d'Essai des Metaux, Zürich.

Li. Chemical symbol for *lithium*.

Lichtenberg's Alloy. (*Onion's Alloy.*) A fusible alloy, melting point 96° C., containing 50% bismuth, 30% lead, and 20% tin. (T. 29.)

Lift. The separation of the *cope* from the *drag*.

Liftability. The term as applied to *moulding sand* describes the ability of a sand to withstand the load and bending applied during the process of stripping the *pattern*, or the lifting of the mould.

Lifter. (*a*) An L-shaped iron bar used to support the sand in the *cope*. (*b*) A moulding tool used to clean and finish the bottom and sides of deep narrow openings.

Lifting Magnet. (See MAGNETIC CRANES.)

Lifting Plate. A small iron plate containing a central hole through which a screw-threaded bolt is inserted. The plate is let into foundry patterns to act as a handle in the removal of the *pattern* from the *mould*.

Lifting Screw. An iron rod screwed into a *pattern* to enable it to be withdrawn from the *mould*.

Light Alloys. A term designating alloys of low specific gravity, e.g. magnesium and aluminium alloys.

Light Metals. Metals having a low specific gravity, such as beryllium, magnesium and aluminium.

Light Sensitive Cell Pyrometer. A *photoelectric cell pyrometer*.

Lightly Coated Electrode. A filler-metal electrode, used in arc welding,

consisting of a metal wire with a light coating applied subsequent to the drawing operation, primarily for stabilizing the arc. (A. 37.)

Lights. Tin plates exceeding 55 lb. but less than 108 lb. per *basis box*, designated as C.L. or C.L.L.

Lignite. A dull brown fuel of low calorific power in a condition between peat and coal.

Lime. (*CaO.*) (See LIMESTONE.)

Lime Bag. A bag of powdered lime used in the foundry. Lime is sprinkled on the parting face of the *drag* and the *cope* is lowered on to it and then lifted and inspected. If the lime has adhered uniformly to the top face the joint is satisfactory.

Lime Coating. (See LIME DIP.)

Lime Dip. (*Lime Coating, Lime Finish.*) A treatment given to steel rods and wire prior to drawing. The coils are dipped in a hot lime suspension to neutralize any traces of acid and to seal the hydrated oxide coating so that this will not form an abrasive rust. Drawing is facilitated by the combination of the lime with the lubricant in the drawing process. (H. 65.)

Lime Finish. (See LIME DIP.)

Limestone. Calcium carbonate ($CaCO_3$) which on calcination yields *lime* (CaO). The term "limestone" includes chalk, marble and dolomite, the last named being a double carbonate of magnesium and calcium ($MgCO_3.CaCO_3$). Immense quantities are used in the smelting of iron in the blast furnace, approximately 8 cwt. for every ton of *pig iron* produced. The *silica* and *alumina* of the ore, having a stronger affinity for the lime and magnesia, form a liquid *slag* which floats on the surface of the liquid iron and can be removed easily. In the *basic steel-making process* an excess of lime is present in the slag, beyond that required to combine with all the silicon and the oxidized phosphorus, otherwise dephosphorization is retarded.

Liming. (See LIME DIP.)

Limit. (*a*) The permissible deviation from a specified dimension. (*b*) In voltage, wave-length or frequency of X-rays, a value, characteristic of the particular chemical element in question, on the two sides of which excitation, absorption, photographic effect or the like, have sharply different values. (A. 27.)

Limit of Proportionality. (*Proportional Limit.*) The stress (load divided by original area of cross-section of the test piece) at which the strain (elongation per unit of gauge length) ceases to be proportional to the corresponding stress. In practice, if deformation is plotted against corresponding values of stress, the relation between the two is found to be at first a strictly proportional one, but with higher values of stress deformation increases at a greater rate than the previous ratio. The limit of proportionality is the greatest stress for which the strictly constant ratio of stress to strain applies, i.e. it is the end of the straight line portion of the graph, and is usually assumed to coincide with the *elastic limit.*

Limiting Creep Stress. A term used somewhat loosely to denote the *maximum stress* at which a material will not *creep* by more than a certain amount within the working life of the part. It is also used in some of the short-time creep tests, as for example, the *Hatfield Time-Yield.*

Limiting Range of Stress. The greatest range of stress that a metal can withstand for an indefinite number of cycles without failure. If exceeded, the metal fractures after a certain number of cycles which decrease as the range of stress increases. When the mean stress is zero, half this range is the *fatigue limit.*

Limiting Ruling Section. (See RULING SECTION.)

Limnite. A hydrated iron oxide containing organic acids with some quartz sand. It is very similar to, but contains more water than, true *limonite.*

Limonite. An iron ore consisting essentially of hydrated ferric oxide. It is the main constituent of *bog iron ore.* (See also MINETTE.)

Lincoln Twin Arc Welding Process. A method in which two wires are fed into a single molten pool of weld metal. Two arcs are maintained by two distinct circuits and follow one another in tandem. Very high welding speeds are obtained by this method. (A. 46.)

Lincolnweld. In this process the bare electrode is inched and positioned directly above the point where the weld is to be produced before the electrode is brought into contact with the job. The appropriate flux then feeds from the hopper until it has formed a blanket deep enough to shield the arc. At this stage, an automatic control button is pressed, starting the welding cycle and producing the hidden arc between the electrode and the parent metal. The resultant arc heat fuses the electrode and the parent metal, and the weld is produced. Since the arc and molten metal are covered by flux throughout the operation, the weld metal is completely protected from contact with the air, and it is claimed that this ensures uniform welds

of highest quality and makes possible the use of extremely high amperage, resulting in faster welding at lower cost. Moreover, because the hidden arc is submerged by the layer of flux, spatter is entirely eliminated. (Z. 7.)

Lin-de-Surfacer. A machine for conditioning the surface of hot billets, blooms or bars as they pass along the rolling mill production line. The operation of removing the surface is accomplished by means of banks of torches. In the most widely used type of machine there are two banks of torches which remove the surface from two opposite sides of the billet as it passes. For the conditioning of four surfaces, two machines may be used in tandem with a manipulator between, or the billet may be passed twice through the same machine. (I. 52.)

Lindblad Furnace. (See GRÖNWALL FURNACE.)

Linde Oxygen Jet. A device used in the rapid melting of scrap. It consists of a central oxygen supply pipe surrounded by two concentric water-cooled passages. Oxygen at 75 to 100 lb. per sq. in. issues from the nozzle at speeds claimed to be in the supersonic range (1300 to 1500 ft. per sec.). The jet is inserted through a charging door wicket hole. Three hoses are coupled to the jet, one for oxygen and the others for inlet and outlet water.

Linde Welding. A process for the butt welding of mild steel pipe. It is based on the fact that the melting point of steel decreases with an increase in carbon content. By using a carburizing flame (excess acetylene), the heated parent material picks up carbon and melts faster than it would do in its original state. It is claimed that increased welding speed is thus obtained, and that by using silicon manganese filler rods, efficient joints are obtained at reduced cost. The welding flame is adjusted so as to obtain an acetylene "feather" which, measured from the blowpipe nozzle, is twice or two-and-a-half times as long as the normal neutral cone.

Line. (*a*) British unit of length; one-twelfth of an inch. (*b*) A possible edge of a *crystal*. (*c*) In X-ray diffraction patterns, a straight or slightly curved narrow region of maximal intensity. (*d*) A group of monochromatic *X-rays*, not necessarily collimated. (A. 27.)

Line Block. A printing block consisting of black and white parts only, without any gradation of tone. It is produced by photography and etched into relief on metal. (Cf. HALF TONE PROCESS.)

Line Focus. In X-ray tubes, a focus having one dimension reduced to such an extent that the focus approximates a segment of a straight line on the target in the plane determined by the axis of the tube and the direction from the target to the irradiated object. This secures the advantages of a point source of X-rays without extreme local heating. (A. 27.)

Line Indices. The smallest integers proportional to the co-ordinate differences, in terms of the parameters (a, b and c), between equivalent points lying on a crystal line, written, in general (HKL); in particular, for example (210). In cubic crystals the line (pqr) is perpendicular to the plane (pqr). (Cf. MILLER INDICES.) (A. 27.)

Line of Magnetic Flux. (*Line of Magnetic Induction.*) A line drawn in a graphical representation of a magnetic field so that its direction at any point is the same as the direction of the field at that point. The line is also commonly used as a unit of magnetic flux, one line being equal to one *maxwell*.

Line of Magnetic Force. (See MAGNETIC LINE OF FORCE.)

Line of Magnetic Induction. (See LINE OF MAGNETIC FLUX.)

Line Pair. In *spectrographic analysis*, the term includes an analysis line and the internal standard line with which it is compared.

Line Softening. A method of heat treating uncoiled steel strip in which the strip is passed through the heat treatment furnace and the process made continuous by butt welding the ends of the coils. (Cf. GANG SOFTENING.)

Line Spectrum. Emission spectrum consisting of definite single lines; characteristic of an element in the atomic state.

Lineage Structure. Deviations from perfect alignment of parallel arms of columnar dendrites growing from a liquid. This type of imperfection may vary from one part of the cast crystal to another. (A. 27.)

Liner. (*a*) A separate sleeve placed within an engine cylinder. It gives additional durability and can be replaced when desired. (*b*) In drop forging, thin strips of material used to pack the space between the dies and the units into which they are fastened.

Lining. This usually refers to the layer of refractory material in a furnace or ladle.

Linishing. The operation of polishing as carried out on a linisher. This machine is designed for the polishing of flat objects and carries a flat revolving cloth belt whose surface is impregnated with a suitable abrasive material.

Linkage, Flux, ϕN. The product of the number of turns in an electric circuit by the average value of the flux linked with the circuit. (A. 28.)

Linnaeite. (See LINNALITE.)

Linnalite. (*Linnaeite.*) Native cobalt sulphide (Co_3S_4).

Linnik Interference Microscope. An instrument by means of which the depth of scratches or other surface imperfections on small objects, such as ball bearings, can be measured by observing the displacement of *interference fringes.*

Linz-Donawitz Process. (*L-D Process.*) A modification of the Bessemer process, using a special type of converter in which the molten pig iron is refined by blowing with oxygen. The oxygen enters the vessel through the mouth by means of a vertical pipe, at the end of which is a special nozzle. This nozzle is made of copper and is extensively water-cooled. It is claimed that under these conditions the phosphorus is burned off simultaneously with the carbon, in contradistinction to the ordinary basic Bessemer conversion, where dephosphorization is delayed until after decarburization and an initial phosphorus content of 0·15% can be reduced to 0·04%. Owing to the intensely high temperature generated where the oxygen jet impinges on the bath, the fluxing of the slag and the formation of a reactive slag takes up little time. It is claimed that the sulphur content of the metal may be reduced by something like 50%, and the final sulphur content of the steel is generally between 0·01% and 0·03%. (I. 70.)

Li_2O. Chemical formula for lithium oxide.

Lip. In a twist drill the edge formed by the intersection of the flank and the face.

Lip Feeder. (See CONNOR RUNNER.)

Lipowitz's Alloy. A low melting-point alloy containing 50% bismuth, 27% lead, 13% tin, and 10% cadmium. Melting point 65° C.

Lipson Thickness Tester. An instrument which employs the electromagnetic principle for determining the thickness of non-magnetic coatings on steel. As a soft iron core is withdrawn from the field of an energized alternating current solenoid, the magnetic pull upon the core increases. If the solenoid is held in a vertical position over a coated steel article and lowered sufficiently to permit the lower end of the core to contact the surface, the distance through which it must be raised for the pull of the solenoid to overcome the attraction of the core for the ferromagnetic basis metal will vary inversely with the thickness of the coating. (L. 37.)

Liptak Heat Treatment Furnace. An air-jacketed heat treatment and forging furnace, which is claimed to be free from the disadvantages which result in low thermal efficiency in many other types of furnace. The furnace is constructed on the suspended arch and wall principle and is encased in a thin outer jacket of insulating material from which the refractories proper are separated by an air space. (M. 120.)

Liquation. (*a*) The separation of metal from *dross* by heating the mixture to the melting point of the metal, the metal being then allowed to flow away while the dross is left behind. (*b*) (See SEGREGATION).

Liquid Blasting. A method of surface blasting with a high velocity stream of abrasive particles suspended in a liquid, which provides an economical means of deburring, descaling and preparing surfaces for finishes. Applications include polishing of parts manufactured to close tolerances, descaling dies, and preparing surfaces of dies prior to plating. (M. 76.)

Liquid Carburizing. A process for carburizing steel by immersion in cyanide salt baths at temperatures between 840° to 950° C. Deep cases of high carbon and low nitrogen content are produced by the decomposition of sodium cyanide in the presence of alkaline earth catalysts. (K. 40.)

Liquid Contraction. The shrinkage of metal in the liquid state as it cools. (A. 26.)

Liquid Disintegration. A term used in powder metallurgy for the dispersion of a stream of molten metal or alloy into particles by means of a gas blast, a liquid jet, or a set of mechanical knives, either one of which crosses the metal stream while revolving at very high speed. (G. 30.)

Liquid Envelope. A trade name for a thin plastic coating which acts as a protective film on metal articles. It is employed for preserving the finish of strip and sheet during deep drawing.

Liquid Honing. (*Vapour Blast.*) A process of surface cleansing, deburring and finishing, based on the use of a fine abrasive mixed with a chemical emulsion, which is discharged by compressed air against the surface to be treated. (P. 42.)

Liquid Nitriding. A method of hardening high speed tool steels in which a mixture of 60% of sodium cyanide with 40% by weight of potassium cyanide is used. This bath must first be aged for 12 to 16 hours at 566° C., as tools nitrided in

fresh baths are brittle. The maximum surface hardness is attained after immersion for 2 to 3 hours at 566° C., increasing the time increases the case depth, but the surface hardness tends to decrease. The process can be applied to all classes of high speed steel. (M. 166.)

Liquid Squeeze. (See TALBOT PROCESS FOR TREATING INGOTS.)

Liquidoid. A term advocated to indicate the beginning of the formation of a new phase from a solid solution, suggestive of *liquidus* which refers to the beginning of the formation of a solid phase from a liquid solution. The term *solidoid* is advocated to indicate the end of the phenomenon, suggestive of *solidus* which marks the end of solidification. (S. 15.)

Liquidus. A line in a binary phase diagram or a surface on a ternary phase diagram, representing the temperatures at which freezing begins during cooling, or melting is completed on heating, under equilibrium conditions, i.e. the line or surface above which all the alloys in the system are completely molten. (See Iron-Iron Carbide Diagram Fig. 7.)

Liquor Finish. A bronze-coloured finish produced on steel wire by immersing it, after pickling and rinsing, in a bath consisting of a dilute solution of copper- and tin-sulphates, with the resultant deposition by chemical replacement of tin and copper on the surface of the wire. The wire is then passed through a second bath containing fermented liquors and is redrawn whilst still wet.

Liquostriction. The change in dimensions of a solid body on immersion in a liquid. This effect may either strengthen or weaken a material. The strength of steel and glass may be decreased by up to 60% in the presence of water and increased by up to 30% in the presence of various organic liquids. This *wetting effect* is important in *corrosion fatigue*, *caustic embrittlement*, *season cracking*, and soldering brittleness. Theoretical considerations indicate that the effect is connected with surface tension and surplus attracting forces in the surface. The magnitude of both the wetting effect and the liquostriction depends on the surface tension of the wetting liquid.

List Edge. The concentration of tin or zinc formed on the lower edge of tinplate or galvanized iron in the hot-dip process, owing to the draining of the coating metal prior to solidification.

Listard Process. A method of chrome hardening carried out under the *Van der Horst* patents.

Litharge. Lead monoxide (PbO).

Lithium. (*Li.*) *Atomic weight* 6·94. *Melting point* 180° C. *Specific gravity* 0·53. A silver-white alkali metal. Its hardness on *Mohs' Scale* is 0·60. It is ductile and can be drawn into wire or rolled into sheet. Lithium-containing gas is claimed to form a protective atmosphere for use in annealing furnaces. (N. 8.)

Lithium Ceramics. Ceramics based upon lithium aluminosilicate under the trade name of *Stupalith*. These materials possess high resistance to thermal shock, and can be produced with properties so controlled as to provide a range of coefficients of thermal expansion, from positive to negative. The ceramics are produced from blends of lithium-bearing minerals and clay or blends of other ceramic raw materials to obtain the desired ratio of lithia, alumina, and silica. (S. 104.)

Lithoform. A zinc phosphate solution for application to galvanized or other zinc or cadmium surfaces as a protection from atmospheric corrosion and as a base for paint.

Lithorizing. A phosphatizing process applied to zinc or cadmium coated surfaces for protection against atmospheric corrosion.

Litmus. A colouring matter used as a reagent to test the acidic or alkaline nature of liquids and solutions.

Litre. The volume of a kilogram of water at 4° C. equal to 1000·028 cubic centimetres

Littrow Monochromator. (See UNICAM S.P.600 SPECTROPHOTOMETER.)

Live Load. A variable load. As for example the traffic over a bridge as distinct from the weight of the structure, i.e. the *dead load*.

Live Pass. (See PASS.)

Lixiviation. (See LEACHING.)

Ljungberg Process. A direct process in operation in Sweden in 1909. The furnace was similar to the blast furnace, with 3 electrodes. The ore and fuel were crushed to a suitable size and fed into the top of the furnace in the usual way, the ore being partially reduced by carbon monoxide rising through the charge. Reduction was completed in the smelting chamber. No air was used in the process, the gases being produced from the carbon in the charcoal and coke, and the oxygen in the ores ($FeO + C = Fe + CO$).

Ljungstrom Preheater. A regenerative air preheater in which the heat is absorbed from the hot gases by thin sheet-metal elements built into a rotor, which, as it rotates, carries them into the path of the air to be heated. (L. 30.)

LL. Reg. *Lloyd's Register of Shipping.*

Lloyd and Jeffrey Micro Hardness Tester. This instrument consists fundamentally of a plunger mounted with a standard Vickers pyramid type diamond. Movement of this plunger is controlled by a calibrated spring, and the springs may be interchanged for varying loads. The plunger may be mounted in place of an objective of a microscope and an impression made. The objective is then replaced in order to measure the impression and the Vickers hardness number calculated using the usual formula. The instrument is so constructed that springs may be quickly changed for different loads and it is equally suited for use with either a conventional type of microscope or an inverted type.

Lloyd's Register Bend Specimen. As used for Class 1 pressure vessels, the specimen has a section $\frac{3}{4}$ in. wide by $\frac{3}{8}$ in. thick, and is machined from the upper surface of the weld transverse to the joint. The specimen thus includes weld metal from the outer layers which has received the least refining effect of subsequent layers. This specimen is bent under free bending conditions until the arms are parallel and the distance between the arms is not greater than $\frac{3}{8}$ in. (P. 16.)

Lloyd's Register of Shipping. 71 Fenchurch St., London, E.C.3. A voluntary association of Underwriters, Shipowners and others which exists for the purpose of surveying and classifying the shipping of the world.

Load. The weight supported by a structure.

Load Couple. A thermocouple for measuring the temperature of the furnace charge, as distinct from the furnace atmosphere.

Load Extension Curve. The curve reveals the load at the *limit of proportionality*, *yield point* and *maximum stress*. The corresponding *nominal stresses* are obtained by dividing these loads by the original area of cross-section. The *true stresses* are obtained by dividing the loads by the actual cross-section of the test piece at the loads in question.

Load Factor. (See TAP DENSITY.)

Loadmeter. An instrument, used in rolling mills. It is essentially a solid cylinder of steel, placed between the loading screw and the top roll bearing. A measure of the load applied to it is obtained from the output of an unbalanced temperature compensated Wheatstone network of electric resistance strain gauges, bonded to the surface of the cylinder. (S. 70.)

Loading. (*a*) In powder metallurgy, the filling of the *die cavity* with powder. (*b*) The term used in deep drawing operations to indicate the actual welding to the surface of the tools of particles of the metal being drawn. (*c*) In grinding, filling the pores of the surface of the grinding wheel with the material to be ground.

Loading Range. That range of stress within which any specific testing machine may be used with the specified accuracy.

Loading Rate. In mechanical testing, the rate at which the stress is applied to the test piece.

Loading Sheet. The part of a die set used as a container for a predetermined amount of powder used for feeding into the *die cavity*. (G. 30.)

Loading Weight. Synonymous with *Apparent Density*.

Loam. A clayey moulding sand mixed with *clay wash* to the consistency of mortar. It is used in the making of *loam moulds*.

Loam-Beater. A rammer used to compact the sand around a pattern.

Loam Board. (See STRICKLE.)

Loam-Cake. A disc of loam thoroughly dried and used as a cover on a loam work mould. It is sometimes perforated with holes through which the metal is poured and the air escapes.

Loam Mill. A mill used for crushing and mixing the materials used in the production of *loam*.

Loam Mould. A type of *mould* used in the production of heavy *castings*, in which the *pattern* may be a mere skeleton of the shape of the casting to be produced or the mould may be *strickled* to shape without the use of a pattern. The mould is built up of brickwork and iron plates and covered with *loam* which is worked to the required form and afterwards burnt on.

Loam Plate. A plate of cast iron used in the foundry as a foundation for a *loam mould*.

Local Action. Corrosion caused by *local cells* on a metal surface.

Local Cell. A cell, the *e.m.f.* of which is due to differences of potential between areas on a metallic surface in an *electrolyte*.

Lock. A change in the plane of the mating faces of forging dies. A *compound lock* is one where two or more changes occur. A *counter lock* is a lock placed in the dies to offset a tendency for die shift caused by a steep lock.

Lock Seam Test. A method of testing the adherence of the zinc coating to the base metal of galvanized sheet.

Locked-Up Stress. (See RESIDUAL STRESS.)

Lode. A vein of metal ore.

Loded Irons. Machinable all-pearlitic grey irons containing high silicon. A typical composition contains about 4% silicon, 2·5% chromium and some molybdenum. (Y. 5.)

Lodestone. (See MAGNETITE.)

Lodestuff. The mineral or gangue content of a *lode*.

Loewy Hydraulic Press Process. A method of shell forging which starts with square billets having flat corners, cut into appropriate lengths, heated in a pusher-type furnace, and brought to the centre of the press for piercing by a rapidly moving conveyor. The piercing mandrel, mounted in vertical position, remains stationary upon a fixed crosshead. The piercing process is performed by forcing the die assembly over the close-fitting flat corners of the billet, under 400 tons pressure, and the billet is pierced and expanded out to the wall of the die as it pushes over the mandrel head. (C. 59.)

Loftus Thermo-Induction Process. A process for raising the temperature of metals by 60 cycle induction heating. It is claimed that the use of low frequency (60 cycles per second) instead of high frequency assures through penetration. Further, it supplies single-phase heating on a three-phase line, with the result that the current and power factor are balanced, thereby uniformly heating the material, e.g. billets.

Logarithmic Scale. A scale of measurement in which an increase of one unit represents a tenfold increase in the quantity measured.

Logometer. A scale for measuring chemical equivalents.

London Chamber of Commerce (Inc.), 69 Cannon Street, London, E.C.4.

London Metal Exchange, Whittington Avenue, London, E.C.3.

Long Eye Test. A test for wire which requires that it shall neither crack nor weaken when wrapped or twisted round itself.

Long Line Current. Current (positive electricity) flowing through the earth from an *anodic* to a *cathodic* area which returns along an underground metallic structure. Generally used only where the areas are separated by considerable distance and where the current results from *concentration cell* action.

Long Ton. British ton = 2240 lb. (Cf. METRE TON and SHORT TON.)

Longitudinal Direction. The direction in a wrought metal product parallel to the direction of working (drawing, extruding, rolling). (A. 27.)

Longitudinal Seam Welding. The making of a seam weld in a direction essentially parallel to the throat depth of a resistance welding machine. (A. 37.)

Longitudinal Sequence. The order in which the increments of a continuous weld are deposited with respect to its length. (See BACKSTEP SEQUENCE, BLOCK SEQUENCE, etc.) (A. 37.)

Looping Rod Mills. (See ROLLING MILLS.)

Loose Flange. A term used in the foundry for a flange that may be drawn independently of the body of a pattern. It is often used in combination with a covering or sash core.

Loose Pack Rolling. An operation used in the production of wide mild steel sheet. The sheet bars are rolled down to about half their intended length, pickled and immersed in water containing powdered charcoal in suspension. After matching to form packs of two to four sheets they are reheated and rolled to the specified length.

Loose Patterns. Patterns which are not attached to a plate.

Loose Pieces. A term used in the foundry for parts which can be detached from the main part of a complicated pattern in order to facilitate its withdrawal from the mould.

Looseness. (*a*) Imperfect adhesion between grains in *moulding sands*. (*b*) Internal porosity in an ingot or casting.

Loosening Bar. An implement used in the foundry to facilitate the separation of the sand from the pattern. It consists of a stiff rod extending upwards from the pattern, through the sand. It is struck from opposite sides to loosen the pattern in the mould before lifting the top parts.

Lorenz's Law. The ratio of the thermal and electrical conductivities of all metals is proportional to the *absolute temperature*.

Lorig Test Piece. A round notched *Charpy impact test piece*; it consists of a cylindrical specimen 2 in. long × $\frac{1}{2}$ in. diam. and carries a grooved central notch having a depth of ·05 in., radius ·005 in., angle 45°.

Losenhausen Fatigue Tester. A machine designed for pulsating loads up to 100 tons in either compression or tension; the vibrating load range is 100 tons, and this can be applied anywhere within the limits of 100 tons compression and 100 tons tension. For example, the pulsations may be from 25 tons compression to 75 tons tension, from zero to 100 tons tension, or ± 50 tons. (I. 68.)

Losenhausenwerke Pendulum Testing Machine. The machine comprises a

U-shaped cast-iron frame, the lower portion carrying the specimen being of specially solid construction. The pendulum is pivoted in such a manner that it is able to swing freely through the narrow U-shaped gap in the frame. The selection of the striking energy is effected by altering the weight of the pendulum and may be either 30 mkg. or 15 mkg. The machine is normally fitted for *Charpy* impact tests, but it can be quickly converted for *Izod* impact tests. (S. 53.)

Losenhausenwerke Portable Ball Hardness Tester. An instrument in which the load is applied to a ball indenter by hydrostatic pressure. The tester is used for measuring the hardness of the interior of cylinders. (W. 53.)

Loss on Ignition. The loss in weight of a dried sample on heating to high temperature.

Lost Wax Process. (*Cire Perdue.*) A process which produces metal castings to an accuracy of 0·002 in.; it involves a master pattern in wood or metal from which a die is made to produce the wax patterns. These patterns are invested in *refractory moulds*, which, after the wax has melted out, are baked and used in casting the metal component. (See also PRECISION CASTING.) (T. 50.)

Loup. (See AMERICAN BLOOMERY.)

Lovibond Tintometer. An instrument used for colorimetric analysis. It employs a series of red, yellow and blue glass slides as permanent colour standards. The slides are marked in units and tenths of units along the whole scale, so that any intensity of any one of the three primary colours can readily be measured in terms of this scale. Compound colours can be quantitatively built up by suitable combinations of the primary slides. Provision is made for standardized lighting conditions, the solution under test being illuminated electrically through blue glass screens which give a source of white light equivalent to average north daylight, which is unaffected by external lighting conditions. (B. 5.)

Low Carbon Steel. Plain carbon steel containing less than about 0·25% carbon.

Low Expansion Alloys. Aluminium with alloying constituents balanced to produce relatively low thermal expansion; they usually contain about 14% silicon, with about 1% copper, 1% magnesium and 2% nickel.

Low Heat Duty Clay. A clay which fuses between 1520° C. and 1590° C. (A. 26.)

Low Melting Point Alloys. (See FUSIBLE ALLOYS.)

Low Temperature Treatment. (See SUB-ZERO TREATMENT.)

Lower Case. (*l.c.*) A term used in the correction of proofs indicating that capital letters should be replaced by small ones.

Lower Punch. In powder metallurgy, the lower member of a die which forms the bottom of the *die cavity*. It may or may not move in relation to the *die body*.

Loxal Process. A method of treating a steel surface prior to enamelling or other finish coating in order to increase rust resistance. The method depended upon the use of oxalic acid instead of phosphoric acid and formed a coating of iron oxalate instead of iron phosphate. However, it was found that the high temperature necessary to bake black enamel was detrimental to the oxalate coating. With paint materials requiring a bake below 300° F. it gives satisfactory results.

L.T. Low tension.

L-Type Hardening Furnace. A furnace, so-called because the preheating section is at right angles to the full heating section and quenching section. A protective gas atmosphere is used; the work is placed in trays and pushed into the preheating zone, at the end of which the trays are pushed sideways into the full heating zone and through this into a water-jacketed cooling chamber where a fan blows cold protective gas over them. It is also possible to withdraw the trays for oil- or water-quenching of the contents. It is claimed that the protective gas-quench is intermediate in effect between an oil- or lead-bath quench and air cooling. (K. 37.)

Lu. Chemical symbol for *lutecium*.

Lubatti Process. An electrothermal process for the manufacture of iron. The process differs from the more usual methods in that a shallow container is used and the iron produced is charged directly into a refining electric furnace. This is claimed to minimize excessive pick-up of carbon and other elements. (Z. 14.)

Lubricating. (*a*) The provision of a lubricant, e.g. oil, graphite, metal soap or molybdenum disulphide to metallic surfaces, in relative motion (e.g. machinery), for the purpose of minimizing friction. (*b*) In powder metallurgy, mixing with or incorporating in a powder some agent to facilitate pressing and ejection of the compact from the *die body*; also applying a lubricant to the die walls and/or punch surface.

Lucite. A thermosetting plastic which, owing to its crystal transparencies, is

used for mounting metallographic specimens. Among its many other applications it is used as a protective coating.

Lüders Lines. (See PIOBERT EFFECT.)

Ludlum Furnace. A three-phase direct arc tilting furnace with three electrodes in a straight line. The furnace has been used with success for the duplexing of grey cast iron, i.e. a refining process which removes the sulphur absorbed during the cupola process.

Ludwig Hardness. (H_L.) The depth of penetration recorded using a 136° (Vickers) pyramid indenter and a pre-loading procedure (10 kg. + 140 kg.).

Ludwig Soret Effect. (See SORET EFFECT.)

Ludwik Principle. The theory first put forward by Ludwik that fracture occurs only when the flow stress becomes equal to a technical cohesion limit.

Lumor Fluorescent Crack Detecting Solution. A solution for detecting both surface and internal cracks in ferrous metals. It contains a material which fluoresces when irradiated with ultra-violet light. In use, the part to be inspected is magnetized, and the solution is applied to its surface by a painting, spraying or dipping process or by pouring the fluid from a non-magnetic ladle. At the same time, the piece is illuminated by an ultra-violet lamp, whereupon surface and internal cracks are revealed as bright green lines, which are clearly seen irrespective of the surface finish of the work. (See also GLOMOR.) (M. 46.)

Lunar Caustic. Another name for *silver nitrate*.

Lundbye Process. A method of chromium plating for increasing the life of high speed steel tools containing up to 0·6% of carbon. The tool edge is sharpened before plating, and no finishing is done after plating. The tool is etched in hydrochloric acid for 30 seconds and then cleaned electrolytically. For the plating process, the anode is preferably lead. Each Imperial gallon contains 28 oz. of chromium trioxide dissolved in water with an addition of 0·28 oz. of concentrated sulphuric acid. The bath is operated at 60° C. with a potential of 3·5 to 5 V. and a current density of 1·5 to 3·5 amp. per sq. in. depending on the material and shape of the work. The plated tool is then immersed in an oil bath at 175° C. for 1 hour. (B. 55.)

Lurgi Process. This process consists of roasting iron ore in a reducing atmosphere, thus forming magnetic oxide of iron which is separated by crushing followed by magnetic separation. The internal structure of the kiln is so designed that the ore is caused to fall in a continuous veil through the current of reducing gases. Burners are distributed throughout the periphery of the kiln so that the roasting and reduction can be controlled in the various zones to the required temperature. Blast furnace gas for reduction passes into the centre of the lower end of the kiln while the gas and air for heating pass in from the circumference of the drum, nearer to the centre and upper end of the furnace. The ingoing ore is crushed to give a maximum size of 0·8 in., while the outgoing concentrate is crushed to 0·15 in. after cooling. (J. 2.)

Lustre. A term used in describing the character of the reflections obtained from the fractured surfaces of minerals and rocks.

Lute. (*a*) A plastic mixture of fireclay, and/or other refractory materials, used to seal up cracks between crucible and cover or between *annealing box* and cover to make a gas-tight joint when heat is to be applied. (*b*) The operation of sealing with clay or other plastic refractories.

Lutecium. (*Lu.*) A rare earth metal, not yet isolated. Its atomic weight has been computed as 174·99, and its specific density as 9·74.

Lye. (*a*) Originally the name given to an alkaline solution obtained by leaching wood ashes with water. (*b*) Any strong solution of the caustic alkalis.

M

McAdam Fatigue Testing Machine. In this machine, the specimen is a rotating cantilever beam loaded at the free end with dead weights. (A. 35.)

McCleary and Wuerful Test. (See WUERFUL HARDENABILITY TEST.)

McDonald Bright Annealing. A recuperative system in which four furnace units are employed. Recuperation is effected by circulating the gas between the units containing the hot, annealed and the cold charges. In the third unit, which has been preheated by recuperation, the position of the fan is altered and internal circulation only employed whilst the charge is heated to the annealing temperature. Similarly, internal circulation is maintained in the fourth unit while it is cooling to the temperature of discharge. (L. 33.)

McDonald Numbers. (See PULSE POLARIZER.)

McElroy-McNutt Process. A method which claims to produce successful

radiographs of metal at temperatures up to 480° C. (W. 28.)

McKee Top. A device for charging a blast furnace.

McKee Wear Gauge. An instrument developed at the National Bureau of Standards which measures extremely small increments of wear, as little as 0·00001 in. under favourable conditions. Narrow diamond-shaped markings that show a definite change in one or more readily measurable dimensions after relatively small amounts of wear are applied to the working surfaces. (T. 39.)

McLachlan Machine. A machine by which pole-figures showing the preferred orientation of crystals in rolled metal sheets may be drawn directly from the X-ray diffraction patterns. Any of the three customary planes of projection may be employed, i.e. normal-transverse, normal-rolling, or rolling transverse. The finished pole-figure is about 9 in. in diameter. (D. 8.)

McMullan Hardenability Test. A method of testing, particularly suitable for shallow-hardening steels. For this test, round or rectangular specimens are prepared with the back face cut at an angle to the face which is to be quenched, so as to form a wedge. By careful selection of the angle between the two faces, full hardness is developed at the thin end, and the increased length of the oblique face across which the hardness readings are taken enables the changes in hardness to be followed more accurately. (M. 19.)

McQuaid Ehn Grain Size Test. A method of assessing austenitic grain size which was first developed in investigating the cause of soft spots on case hardened steels. A specimen of steel from which all scale has been removed is carburized in a solid medium for 8 hours at 925° C. The size of the pearlite crystals, which indicates the size of the original austenite grain, is easily seen by the surrounding membranes of excess Fe_3C (*cementite*). The grain size is measured at 100 diameters and compared with standard charts. The figures range from No. 1, very coarse, to No. 8, very fine.

McWilliam, Andrew, C.B.E., D.Met., A.R.S.M. (1867-1922.) Assistant Professor of Metallurgy at Sheffield University, and, for a time, metallurgist to the Tata Iron and Steel Company.

M. (See INDUCTANCE, MUTUAL.)

Machinability. The relative ease with which a material is machined by cutting tools in operations such as *turning, drilling, milling, broaching, threading, reaming* and *sawing,* e.g. the speed at which the material may be cut under different conditions for a given tool life; the force, energy or power required in cutting; the surface finish produced; or the dimensional accuracy maintained under given conditions between like pieces.

Machine Cast Pig. (See CHILL CAST PIG.)

Machine Finish. The surface condition obtained by turning or cutting operations.

Machine Forging. (*a*) A process carried out in a *forging machine* comprising a heavy steel body in which are two dies, one of which is stationary and the other movable. The work is placed on the fixed die, and the machine is started up, causing the movable die to grip the stock and hold it firmly against the fixed die. A formed heading or shaping tool then moves forward and presses against the blank, compelling it to flow into the impressions of the fixed die. The movable die is then withdrawn to its original position. If a single stroke is inadequate, the blank is taken to a second die position. If, however, one stroke suffices, the blank, now a complete forging, is taken out, and can be sheared or punched off the bar immediately. The flow of the metal is identical with that of drop forged material, i.e. in the direction of least resistance, but one great distinction must be drawn between the two operations. In *drop forging*, the blow is a short, sharp impact. In machine forging, it is a strong and continuously increasing thrust. (*b*) The product of the forging machine or upsetter. (L. 42.)

Machine Moulding. The use of mechanical methods for the ramming of moulding boxes and the withdrawing of patterns. The main types in use are: squeezing of the sand into the box by hydraulic or pneumatic pressure, jolting of the box and pattern together which compresses the sand, directing a stream of sand into the box at high velocity by a fan-blade type impeller.

Machine Scarfing. The removal of surface defects from a slab, bloom or billet, by means of multiple oxygen-acetylene torches, during some stage of the rolling operation, while the slab is still at rollable temperature. (S. 45.)

Machine Straightening. Straightening by mechanical means such as the *reeling* of tubes, or *spinning* of wire rod by feeding it through rotating rollers or dies.

Machined Surface. The surface produced by a cutting tool.

Machining. The operation of *turning, planing, broaching, threading, reaming, milling, grinding, drilling, sawing,* by

power-driven cutting tools. It is essentially the action of an edged cutting tool and consists in bringing to bear upon a very small area of metal a stress sufficiently intense to produce rupture.

Macle. (*a*) A variety of andalusite ($Al_2O_3.SiO_2$). (*b*) The French term for a *twin crystal*.

Macro Axis. The long axis in a crystal in which there are three unequal axes.

Macro Etch Test. (*Acid Etch.*) A method of deep etching with acids or other reagents in order to reveal the *macrostructure* and the presence of defects.

Macro-Print. A term sometimes used for an *ink* or *contact print*.

Macrograph. A graphic reproduction of any object which has not been magnified more than 10 diameters. When it is desired to indicate that it is a photographic reproduction, the term *photomacrograph* may be employed. (A. 28.)

Macrography. The study of *macrostructures*.

Macroscopic. Visible either to the naked eye or under low magnifications (up to about 10 diameters).

Macrosection. A metal specimen whose surface has been polished and etched to reveal the *macrostructure*.

Macrostresses. Stresses that exist on a long-range scale between different parts of a specimen, and arise from both the phase change and the thermal gradients set up during the quenching.

Macrostructure. The general crystalline structure of a metal or alloy and the distribution of impurities as seen on polished and etched surfaces, either by the naked eye or under magnifications of less than 10 diameters. In steel the macrostructure is generally related to the primary crystallization.

Madaras System. A method of obtaining pig iron, developed by Dr. Madaras in the U.S.A. The process consists of charging a retort with a mixture of iron ore, coal, and enough water to form a paste; injecting compressed air at 2 to 4·2 kg./sq. cm. pressure and at 815° to 930° C. to burn the coal. In a few minutes the entire mineral charge is heated to 980° to 1095° C. which is the optimum range for hydrogen reduction; injecting hydrogen at a temperature of 815° to 925° C. at 2 to 8 kg./sq. cm. pressure so that it penetrates the entire mass and reacts with the iron oxide to produce steam and metallic iron. About 50% of the injected hydrogen reacts with the ore to produce sponge iron. Sulphur is oxidized by the hot air and is eliminated by the hydrogen. (N. 3.)

Madsenell Process. An electropickling process used for steel in which the work is made the anode in a bath of sulphuric acid with an electric current at about 12 volts. The object of the process is to improve the surface of the steel prior to further treatment and is not intended to be used primarily for descaling.

Maerz Port. A modified type of *port* for an open hearth furnace. It contains a removable block and is designed with the view to facilitating quick removal and replacement of those parts of the gas and air ports which are subject to destruction due to the action of outgoing gases. It has the following characteristic features: (i) Air and gas uptakes are separated, air ports being closer to the furnace bath. (ii) Air uptakes provide for incoming air at high velocities. (iii) Some parts of the port are movable and can be substituted at will. (O. 13.)

Magazine. The core sand container of a core blower. (A. 26.)

Magclad. A name that has been applied to magnesium alloy sheet, clad with layers of a more anodic magnesium alloy. (A. 27.)

Magna Eye. An attachment for magnifying the vernier scales on calipers and height gauges. (M. 146.)

Magnaflux. A non-destructive method for revealing defects in steel. The test consists in magnetizing the steel specimens in such a way as to cause a minute magnetic pole at the edges of any *seam* or discontinuity at or below the surface. On dusting the steel with finely divided iron particles or immersion in a light oil carrying iron particles in suspension, the presence of the defect is immediately revealed. (See MAGNETIC CRACK DETECTION.)

Magnaglo. (See MAGNETIC CRACK DETECTION.)

Magna Scanning. A combination of two radiographic techniques—magnification and scanning. The magnification is accomplished by direct geometrical enlargement, with the film placed at some distance from the specimen. In scanning, the betatron is rotated during the exposure. It is necessary that the focal spot remain effectively fixed in space while the betatron rotates, with only the direction of the emitted X-ray beam changing. (H. 4a.)

Magnefer. Dead burned *dolomite*.

Magne Gauge. A device for determining the thickness of coatings, e.g. of non-magnetic coatings on iron or steel or of magnetic coatings on non-magnetic base metals. It is based on the measurement of the surface magnetic properties, i.e. it measures the force required

to break the hold of a standard permanent magnet from the specimen.

Magnesia. Magnesium oxide (*MgO*). *Melting point* 2800° C.

Magnesia Alba. Commercial basic magnesium carbonate of variable composition.

Magnesia Covering. Hydrated magnesium carbonate containing about 15% asbestos, used for heat insulation.

Magnesite. Strictly, this name should be applied to minerals consisting essentially of magnesium carbonate ($MgCO_3$), e.g. Austrian magnesite, associated with ferrous carbonate ($FeCO_3$) in solid solution (*breunnerite*), but the term magnesite is now generally used for materials consisting mainly of *magnesia* (MgO) including sea-water magnesia. For use in the manufacture of *magnesite bricks*, the mineral is first calcined at 1500° to 1750° C. (depending on the nature and amount of impurities) to expel CO_2 and produce the stable form of MgO, *periclase*, which is resistant to hydration. Higher proportions of impurities lower the temperature required to produce fully shrunk or dead-burned magnesia. The crushed and graded material is then mixed with water and suitable binders and pressed at 2 to 5 tons/sq. in. to form bricks. These may subsequently be fired to 1400° to 1500° C. or supplied chemically-bonded but unfired. Chemically-bonded bricks derive their strength from a bond of magnesium sulphate (added to or developed in the brick batch) whilst fired bricks are strengthened with sulphite lye before firing and afterwards by crystal growth of periclase and formation of magnesio-ferrite ($MgO.Fe_2O_3$) and minor amounts of silicates. A small amount of chromite or alumina (up to about 5%) is often added to improve resistance to thermal shock.

Magnesite Bricks. Refractory bricks used in basic open-hearth furnaces, arc furnaces and hot metal mixers. They are often replaced by stabilized *dolomite* bricks below the hearth and by chrome-magnesite bricks above. Extensively used in the copper and cement industries. Metal-clad magnesite bricks have similar applications.

Magnesite-Core-Moulding Process. (See WEIBERG MAGNESITE CORE-MOULDING PROCESS.)

Magnesium. (*Mg.*) *Atomic weight* 24·32. *Specific gravity* 1·74. *Melting point* 651° C. A very light silvery-white metal which burns in air with a brilliant white light when ignited. It is found in *magnesite*, *dolomite* and other minerals, and in sea-water, and it is used as a deoxidizer in copper and nickel alloys. Magnesium-base alloys are used extensively in the aircraft industry, and magnesium is a constituent in many aluminium and zinc-base alloys. Magnesium has been used as a desulphurizing agent in steel where it is added to the molten metal in the form of a nickel-magnesium alloy. Small amounts of magnesium added to cast iron produce a nodular graphite structure without subsequent heat treatment. (See CAST IRON.) Further, it is claimed that the addition of about 0·25% magnesium to ferritic stainless steels, of the type containing 28% chromium, 3% nickel and 1·5% molybdenum, leads to improved ductility. (Z. 11).

Magnesium Limestone. *Dolomite.*

Magnet. A mass of iron or other material which produces a magnetic field external to itself, and is capable of attracting or repelling the same or another metal. Such a body is surrounded by a magnetic field of a shape and size depending on its characteristics. *Electromagnet.* A temporary magnet formed by winding a coil of wire round a piece of soft iron, the iron becoming magnetic when an electric current flows through the wire. A *permanent magnet* retains its magnetism after it has been removed from an external magnetic field (see MAGNET STEELS), whilst temporary magnets, although they are readily magnetized in a magnetic field, retain very little magnetism when removed from that field. Pure iron and *transformer irons*, for example, are temporary magnets.

Magnet Steels. Materials possessing a high *remanence* and *coercive force*. Tungsten magnets, containing about 6% tungsten and 0·6% to 0·7% carbon, when water-quenched from 850° C., possess a coercive force, varying with the carbon content, from 58 to 72 and a remanence of the order of 10,000. A steel containing 1% carbon with 1·4% chromium gives satisfactory results for this purpose, whilst the addition of up to 1% chromium to ordinary 6% tungsten magnet steel increases the coercive force without impairing the remanence. The *Honda steels*, containing 20% to 60% cobalt and 3% to 9% tungsten and 1·5% to 3% chromium, oil-quenched from 950° to 1000° C., give a coercive force of 220 to 250 with a remanence of about 10,000. The *Mishima alloys*, with 20% to 30% nickel, 9% to 12% aluminium and the remainder iron, possess a coercive force of up to 700 oersteds with a remanence of the order of 10,000. Alnico 2, containing approximately 12% cobalt, 17% nickel, 10% aluminium and 6%

copper, after suitable treatment, will give a coercive force of 560 oersteds with a remanence value of 7300 gausses whilst Alnico 5 (Alcomax) containing 24% cobalt, 14% nickel, 8% aluminium and 3% copper, can be treated to give 550 oersteds with a remanence of 12,500 gausses.

Magnetic Ageing. The decrease in *magnetic flux density* sustained by *magnet steels* immediately after hardening, the rate of loss decreasing with time. Although this phenomenon was a serious detriment in the older types of magnet steels, it occurs only to a very minor degree in modern types of magnetic materials.

Magnetic Alloys. Alloys of iron with silicon, nickel or other elements, which possess high permeability and *low hysteresis* losses.

Magnetic Annealing. A treatment applied to high nickel iron alloys with the object of increasing their permeability. The part is first raised to a temperature above 600° C. and then subjected to a strong magnetic field at 500° C.

Magnetic Change. The temperature at which alpha iron becomes non-magnetic on heating (Ac_2), and conversely that at which it becomes magnetic on cooling (Ar_2). This temperature in the case of pure iron is 768° C. and is known as the *Curie-* or *magnetic transformation-point.*

Magnetic Circuit. A closed path of magnetic flux, the path having the direction of the flux at every point. (A. 28.)

Magnetic Comparator. A magnetic testing device for sorting steel bars, consisting of two test coils with an amplifying instrument and a milliameter. One coil is placed over the end of a standard bar, and the second coil is placed over the bar to be tested; any difference in the magnetic permeability is indicated by the instrument.

Magnetic Crack Detection. (*Magnetic Particle Method.*) A non-destructive method for the detection of defects in the structure of materials. The machines employed are generally of the rectified alternating current or the storage-battery type, and two methods of magnetizing are used, circular and longitudinal, the method chosen depending upon the type of defect expected. A magnetic field is built up in and around the part under inspection and, if a crack or discontinuity be present, north poles will be formed on one edge and south poles on the other, so setting up lines of force. The detecting agent used is referred to as magnetic fluid, or detecting ink, which consists of a thin oil vehicle, such as paraffin, containing a proportion of small particles of magnetic iron oxide in suspension, the particle size being of the order of a few microns. When the fluid is washed over the surface of an article which is magnetized, magnetic poles which occur at discontinuities, such as cracks or inclusions, cause the particles to be attracted and collected at the poles, thereby indicating the location of the defects. The method has been designated by the trade name "*Magnaflux*" when used with visible light and "*Magnaglo*" when used with ultraviolet light. The latter method is used for the examination of the interior of tubes, the powdered pattern obtained appearing as greenish yellow lines against a dark background. (W. 45.) (I. 72.) (See Plate XI.)

Magnetic Cranes. (*Lifting Magnets.*) Power-operated cranes provided with magnets instead of hooks which are energized by direct current. Such magnets can handle loads of any magnetizable material effectively and cheaply, the material to be lifted being gripped or released instantaneously. (I. 71.)

Magnetic Dilatometer. An expansion apparatus, incorporating a pendulum and a magnetic system. The specimen, in the form of a rod ½ in. in length, is situated at the closed end of a silica tube in the uniform temperature zone of a cylindrical electric furnace. Expansion is communicated by means of a silica tube to the pendulum, and the magnified movement at the lower end of the pendulum is considerably further magnified by the magnetic system. The principle involved is that lateral displacement of an iron element in a curved *magnetic field* results in considerable rotation. Visual or photographic observations are made with a lamp and scale, and a correction is made for unwanted expansions. The apparatus is stated to be particularly suitable for investigating the anomalies which exist in the expansion of metals and alloys. (R. 24.)

Magnetic Energy Product Curve. The curve obtained by plotting the product of the co-ordinates of the demagnetization curve (B_dH_d) as abscissae against the induction B_d. (B_dH_d) max. corresponds to the maximum value of the external energy. (A. 28.)

Magnetic Etching. A method for the metallographic identification of ferromagnetic phases, in which a polished surface is covered with a thin colloidal suspension of magnetic particles and a

magnetic field applied. A visible concentration of the colloid over the magnetic areas results and the magnetic and non-magnetic phases are clearly defined. Also used for *Magnaflux*. (H. 25.)

Magnetic Field. A region in the neighbourhood of an electric current or of a permanent magnet, in which forces due to the current or magnet can be detected.

Magnetic Field Strength. (*H.*) (*Magnetic Force.*) The force which produces the *magnetic flux density* at any point, i.e. the *magnetizing force*.

Magnetic Flux. (ϕ.) A condition produced in the medium in the neighbourhood of electric currents or magnets. The amount of magnetic flux through any area is measured by the quantity of electricity caused to flow in an electric circuit of given resistance bounding the area when the circuit is removed from the *magnetic field*. Unit magnetic flux in the electromagnetic system is that flux the removal of which from a circuit of unit resistance causes one electromagnetic unit of electricity to flow in the circuit. The c.g.s. unit of magnetic flux is called the *maxwell*.

Magnetic Flux Density. (*B.*) (*Magnetic Induction.*) The normal *magnetic flux* induced by a *magnetizing force, H,* measured in lines or *gauss* per sq. cm.

Magnetic Flux Welding. The use of a granular flux of a magnetic metal in addition to a bare electrode wire to produce the alloying elements of the weld metal as well as providing the fluxing for the slag. (T. 32.)

Magnetic Force. (See MAGNETIC FIELD STRENGTH.)

Magnetic Force Welding. A method of spot and projection welding in which the magnetic force of the welding current is used to produce a rapidly rising pressure on the work. Initially there is a high contact resistance and, therefore, adequate heat is developed even when welding metals of high electrical conductivity. (Z. 13.)

Magnetic Hysteresis. The lagging of the *magnetic flux density* (*B*) behind the *magnetizing force* (*H*) during reverse magnetization.

Magnetic Hysteresis Loop. A closed figure formed by plotting the *magnetizing force* (*H*) against the *magnetic flux density* (*B*) when the former is taken through a complete cycle after initial magnetization, the magnetic hysteresis loss being proportional to the area of this loop.

Magnetic Induction. (See INDUCTION, MAGNETIC.)

Magnetic Iron Ore. (See MAGNETITE.)

Magnetic Line of Force. An imaginary line in a magnetic field which at every point has the direction of the *magnetic flux* at that point. (A. 28.)

Magnetic Materials. (*Ferromagnetic Materials.*) Certain alloys having a magnetism similar or even greater than that of iron. Iron, nickel and cobalt are the metals possessing the property of magnetism, but other elements which are non-magnetic under certain conditions, when alloyed in certain critical percentages, can be treated to give excellent magnetic properties. (See MAGNET STEELS.)

Magnetic Oxygen Recorder. The design of this instrument is based on the so-called *magnetic wind* principle, which owes its efficacy to the fact that, of the common gases, only oxygen and nitric oxide are attracted by a *magnetic field*. To obtain a sample of the gas for analysis, a refractory filter is inserted at one of the gas passes. The sample is induced through the filter by an aspirator fitted to the oxygen analyser and carried through pipes to a measuring cell—an annulus with a horizontal glass by-pass tube. This by-pass tube carries on the outside two identical, adjacent platinum windings, which are joined in a *Wheatstone Bridge* circuit and become heated when a voltage is applied across the bridge. One of the windings only is traversed by an intense magnetic field from a large permanent magnet. When the gas sample enters the measuring cell, oxygen is attracted into the by-pass by the magnetic field. As it becomes heated by the winding it loses magnetic susceptibility, is displaced by cool gas, and passes along the by-pass into the annulus. This continuous gas flow, or magnetic wind, causes differential cooling, and thus, differing electrical resistance, in the two windings on the by-pass, unbalancing the bridge. The resulting out-of-balance e.m.f. is measured by a standard potentiometer/recorder and is proportional to the oxygen content of the sample. (I. 17.)

Magnetic Particle Method. (See MAGNETIC CRACK DETECTION.)

Magnetic Permeability. The ratio of the *magnetic flux density* (*B*) to the *magnetizing force* (*H*).

Magnetic Potential Difference. The line integral of a magnetizing force between two points in a *magnetic field*. (A. 28.)

Magnetic Properties. The most important characteristics of magnetic alloys are: (1) *hysteresis loss* on passing through a magnetic cycle and arising from internal magnetic friction; (2) *eddy current loss* due to electric currents

induced in the material by changes in flux. (3) *Magnetic permeability.* (4) *Saturation value.* (5) *Coercive force.* (6) *Remanence.*

Magnetic Pulley. A device, actuated by magnetic attraction, for mechanical separation of metal from sand. (A. 26.)

Magnetic Pyrites. The mineral *pyrrhotite* consisting of ferrous sulphide containing variable amounts of dissolved sulphur. It often contains nickel and thus becomes a valuable ore.

Magnetic Roasting Process. The essential feature of this process is that of heating iron ore in the presence of air in order to oxidize the iron content, present in whatever form, to the magnetic oxide so that in a subsequent operation it may be separated from the *gangue* by means of a *magnetic separator.*

Magnetic Separator. A device used to separate magnetic materials from less magnetic or non-magnetic materials. The crushed material is separated while travelling on a conveyor belt past a magnet. (A. 27.)

Magnetic Sorting. This method depends on the fact that for any given steel there is a relation between the *hardness* and the magnetic properties and in certain cases the relation is sufficiently sensitive to enable magnetic measurements to be used as a check on hardness. The test is carried out in various ways. In one method, two magnetizing coils form the arms of a 50-cycles-per-second bridge circuit, the other two arms being the windings of a centre-tapped transformer. The bar under examination is passed through one of the magnetizing coils with a standard bar in the second magnetizing coil. When the coils forming the four arms of the bridge are carefully matched and the test bar has the same magnetic properties as the standard, there is no out-of-balance voltage, but if the magnetic properties are different from those of the standard, the bridge is unbalanced and the out-of-balance voltage can be fed to a suitable indicator. The test is non-destructive and is capable of detecting lack of uniformity which might escape observation under normal methods of hardness testing.

Magnetic Sorting Bridge. (See SALFORD MAGNETIC SORTING BRIDGE.)

Magnetic Transformation Point. (See MAGNETIC CHANGE.)

Magnetic Viscosity. The time lag between the increase of a *magnetic field* and the resultant magnetization. It occurs in most ferromagnetic substances and is accounted for, almost completely, by *eddy-current* formation. (S. 148.)

Magnetic Wind. (See MAGNETIC OXYGEN RECORDER.)

Magnetician. One skilled in the practice of magnetic measurements. (A. 28.)

Magnetics. That branch of science which deals with the laws of magnetic phenomena. (A. 28.)

Magnetism. The science of magnets and their fields of force; the property of certain bodies to attract or repel other bodies, the force being distinct from gravitational and electrostatic forces, exhibited by lodestone, liquid oxygen (see MAGNETIC WIND) and iron in a *magnetic field.*

Magnetization Curve. (*B/H Curve.*) A curve showing the variation in *magnetic flux density* (B) from zero to saturation as the *magnetizing force* (H) is increased.

Magnetite. (Fe_3O_4.) (*Magnetic Iron Ore.*) Natural black oxide of iron.

Magnetizing Current. (See CURRENT, MAGNETIZING.)

Magnetizing Field. The region in the neighbourhood of a permanent magnet or a current-carrying conductor in which magnetic forces can be detected.

Magnetizing Force (H). The force which produces a *magnetic flux density* (B) expressed as a number of *lines of force* per sq. cm.

Magnetizing Force, Incremental, HΔ. One half the algebraic difference of the maximum and minimum values during a cycle of periodic magnetizing force. (A. 28.)

Magneto Acoustic Test. A non-destructive test for the detection of cracks in steel. The part is placed in a strong magnetic field whilst a search coil, to which earphones are connected, explores its surface. Any discontinuity in the steel caused by the presence of a crack or non-metallic inclusion produces an irregularity in the magnetic field which in turn induces an e.m.f. in the search coil which is heard in the earphones.

Magneto Chemistry. A branch of physical chemistry dealing specifically with the magnetic properties of chemical substances.

Magneto-Ohmmeter. An ohmmeter embodying a magneto-generator.

Magnetoelastic Energy. The part of the energy of a crystal which arises from the interaction between the magnetization and the mechanical strain of the lattice. The magnetoelastic energy is defined to be zero for an unstrained lattice. (K. 28.)

Magnetographic Inspection. A term covering various methods for revealing defects in ferromagnetic materials in which the principles of magnetism are applied, e.g. *Magnaflux.*

Magnetomotive Force. (*J*.) The force which tends to produce a *magnetic field*. In magnetic testing it is most commonly produced by a current flowing through a coil of wire, and its magnitude is proportional to the current, and to the number of turns. The *c.g.s. unit* of magnetomotive force is called the *gilbert*. (A. 28.)

Magnetostriction. The change in dimensions occurring in magnetic materials brought about by magnetization or conversely the changes in magnetic properties produced by mechanical stresses. The changes in length parallel to magnetization in a specified direction, or perpendicular to that direction, are called, respectively, the longitudinal or transverse *Joule effect*. Usually when the length is increased the transverse dimensions are decreased and vice versa so that the resulting change in volume, i.e. the *Barrett effect*, is extremely small. The bending which accompanies magnetization is known as the *Guillemin effect*, whilst the twist resulting when circular and longitudinal fields are applied simultaneously to a rod specimen is called the *Wiedemann effect*. Each of these mechanical effects has its reciprocal magnetic effect. With the application of tension or compression the resulting change in magnetization parallel to the direction of the stress is called the longitudinal *Villari effect* and the change in magnetization perpendicular to this direction is the transverse Villari effect. Thus, the Villari effects are the converse of the Joule effects. There is also a converse of the Guillemin effect, namely, the change in magnetic flux produced by bending a ferromagnetic rod in a longitudinal magnetic field. The longitudinal magnetization due to twisting a circularly magnetized rod is the inverse *Wiedemann effect*. The closely associated effect in which circular magnetization is produced by twisting a longitudinally magnetized rod is called the *Wertheim effect*. Finally, the change in magnetization resulting from a change in volume is called the *Nagaska-Honda effect* and is a reciprocal of the *Barrett effect*. (W. 55.)

Magnetostriction Generator. A device for producing ultrasonic waves by means of the dimensional change of a ferromagnetic material when subjected to an alternating magnetic field. (B. 124.)

Magnification. The ratio of the size of the image to that of the object. Magnification is generally expressed in diameters, thus: × 100 or 100 diameters. (A. 28.)

Malrey Process. A method for the centrifugal casting of pipes in which a stream of finely powdered ferro-silicon is fed into a revolving mould just ahead of the molten metal. This provides a method of controlling the conditions of cooling and prevents the molten metal from being chilled on contact with the mould walls. (S. 95.)

Malachite. A mineral consisting of basic cupric carbonate.

Malcolmizing. A process for surface hardening stainless steel. The work is placed in sealed containers, fitted with gas inlet and outlet tubes. Dissociated ammonia is passed over to reduce any oxides which may have formed on the surface of the metal. This preliminary treatment is carried out at a temperature not exceeding 455° C. for a period of not less than four hours. In the next step, the ammonia is by-passed from the dissociation into an ionizer, where it is subjected to an electric discharge and thence passes through the container. During this final treatment the temperature is maintained between 495° and 565° C. for a period of time depending on the type of stainless steel involved and the depth of case desired. Approximately 30 hours are required for a case depth of 0·075 in. It is claimed that the surface hardness of any of the basic types of stainless steel can be increased up to 1100 Brinell, with a corresponding improvement in resistance to wear, erosion and seizing, and that the hardness is retained for long periods of time, even when the steel is used at elevated temperatures. (M. 67.)

Malleability. The property which enables a metal to be mechanically deformed under compression, as in hammering or rolling into thin sheets without cracking. (See DUCTILITY.)

Malleable Cast Iron. (See CAST IRON.)

Malleable Iron. The term usually means *malleable cast iron* but in the U.S.A. it is sometimes applied to *wrought iron*.

Malleable Nickel. Nickel which has been commercially refined and treated with a deoxidizing agent such as magnesium. After this treatment, the nickel can be drawn, forged or rolled into sheets.

Malleable Pig Iron. Pig iron of composition suitable for production of white cast iron for malleablizing. (Cf. MALLEABLE IRON.)

Malleablizing. The process of producing *malleable cast iron*.

Manchester Furnace. An annealing furnace, characterized by the fact that it is equipped with recuperative flues, situated at the sides of the firebox, for preheating the air. It is fired by coal or coke.

Mandrel. (*a*) An accurately turned shaft on which work already bored is mounted for turning, milling, etc. If partially split and capable of expansion by a tapered plug it is called an *expanding mandrel.* (*b*) The headstock spindle of a lathe. (*c*) A *rod* used to retain the cavity in hollow metal products during working. Thus, *hollow forgings* are made on a mandrel, pierced *billets* are rolled on a mandrel to form tubes; whilst the internal dimensions of tubes are maintained during *cold drawing* by *drawing* over a mandrel. (*d*) A piece of wood, suitably curved and grooved, formerly used for the hand-making of springs.

Mandrel Drawing. (See BAR DRAWING.)

Mandurometer. (See ERNST HARDNESS TESTER.)

Manganese. (*Mn.*) *Atomic weight* 54·94. *Melting point* 1245° C. *Specific gravity* 7·39. The so-called pure manganese containing less than 0·1% of impurities and obtained by distillation is silver-grey in colour, but the metal obtained by electrodeposition is silver-white. The two most important manganese ores from the commercial point of view are *pyrolusite* and *psilomelane*. Manganese metal of the highest purity is obtained by the electrolysis of a solution of manganous chloride, using a mercury cathode. Other methods of preparation include: the thermit process, in which the oxide Mn_3O_4 is reduced by aluminium; and the reduction of manganese dioxide with carbon in the electric furnace. The metal thus obtained by these processes may be further refined by distillation. The metal manganese has no commercial application, but it is used extensively as an alloying addition, e.g. *manganese bronze*. It is added to steel in the form of *ferro-manganese*, *spiegeleisen* or *silico-manganese*. The almost universal use of manganese for deoxidation causes it to be present in small quantities in nearly all steels. When in excess of the quantity required to remove oxygen and to combine with sulphur, it hardens ferrite but somewhat reduces ductility. Small additions, up to say 1½% manganese, with suitable adjustment of the carbon, improve the forging properties, but in such quantities as 2½% the effect is harmful. Manganese has a powerful influence on hardenability and as such is a useful alloying element. Steels containing about 1½% manganese and up to 0·4% molybdenum are used for such purposes as automobile crankshafts, medium tensile bolts, shafts and spindles in general engineering. Austenitic manganese steels containing about 14% manganese and 1% carbon give extremely high resistance to abrasion due to their great work-hardening capacity. They are non-magnetic and their coefficient of expansion is nearly twice that of ordinary steel. Manganese steel of this type is used for rail points, rock crusher parts, dredger buckets, etc.

Manganese-Aluminium. A *hardener alloy* employed for making additions of manganese to aluminium alloys such as *Duralumin*. Manganese lowers the *thermal conductivity* of aluminium but increases the strength. Up to 1·5% manganese is used in aluminium alloys where strength and stiffness are required. A typical alloy contains 25% manganese and 75% aluminium.

Manganese-Boron. An alloy containing 20% to 25% boron and 60% to 65% manganese. It is used as a deoxidizing and degasifying agent.

Manganese Bronze. A high tensile brass containing 3·5% manganese. It is used both in the cast and wrought form and is characterized by great strength and toughness and excellent resistance to corrosion, particularly to sea-water. It is used for propeller blades, and parts requiring high strength and resistance to sea-water. It contains no tin and is, therefore, not a true bronze.

Manganese Casting Brass. A brass, usually *muntz metal*, containing a small amount of manganese, with or without iron and tin. It has a high tensile strength. A typical alloy contains 58% copper, 40% zinc, and 2% of a master alloy consisting of tin, iron, manganese and aluminium. The lead content is not permitted to exceed 0·15%.

Manganese Iron. A 14% manganese malleable cast iron. The carbon content of the initial casting is 3% to 3·5%, but on decarburizing this is reduced to 1%. The main properties are the toughness and high resistance to both wear and shock. This metal possesses two disadvantages, namely, the limit of size in casting (⅝ in. to ¾ in. section of any length), and difficulty of machining. (H. 13.)

Manganese Ore. (See RHODOCHROSITE.)

Manganese Spar. (See RHODOCHROSITE.)

Manganese Steel. (See MANGANESE.)

Manganese Sulphide. A slate-grey microconstituent, which exists as a metallic inclusion in iron and steel. It is formed by the manganese in the steel combining with the sulphur It is normally present in steel as an impurity and in mere traces, depending upon the quality of the steel, but in free machining steels it is added for the purpose of promoting machinability.

Manganite. (*Grey Manganese Ore.*) A hydrated manganese oxide ($Mn_2O_3.H_2O$).

A minor ore of manganese, usually found with other manganese minerals and iron.

Manganoferrite. (See FERROFERRITE.)

Mangling. Flattening plates by passing between rollers, the plates being either in the hot or cold condition.

Manipulators. Large side guards, set at right angles to the rolls and capable of movement across the roll table, used to guide the steel into the various passes in the mill. They may be powered by hydraulic cylinders or by electric motors.

Mann Tension Impact Testing Machine. A machine consisting of a pendulum for measuring the energy required to rupture the test specimen and a rotatable wheel to develop the necessary kinetic energy and velocity. The specimen and tup are attached to the pendulum. The wheel is brought up to the desired velocity and retractable horns are released striking the tup and thereby rupturing the specimen. (M. 72.)

Mannesmann Powder Process. A method for the production of metal powder in which molten iron containing about 4% of carbon is poured in a thin stream from a tundish so that it falls through the middle of an annular jet several inches in diameter. This jet is fed by high pressure air and is so designed that the air leaving the inside of the annular ring is directed downwards to form a vortex some distance below the ring. When the metal reaches this point it is rapidly disintegrated. The particles are roughly spherical in shape and have a highly oxidized skin with a high-carbon core. The powder is heated by passing it through a tunnel kiln in sealed containers, where the oxide skin is reduced by the carbon in the powder, yielding spongy hollow spheres. (M. 142.)

Mannesmann Tube Piercing Mill. A rolling mill for the production of seamless steel tubes. It consists of two double-conical rolls turning in the same direction. Each roll rotates at an angle to the workpiece with the centre lines of the roll shafts lying in parallel planes. A billet heated to the correct piercing temperature, 1100° to 1260° C., is pushed into the mill, where the rolls engage it and start the spinning action. Because the rolls are at an angle to the billet, the component of force in the longitudinal direction pulls the billet forward over the piercing point. As the billet travels forward between the rolls, it meets the piercing point which is placed at a fixed distance beyond the first point of roll contact. The metal immediately starts to flow around the piercing point, thus forming a tube at the average rate of one foot per second, the piercing point acting as an internal roll. (T. 26.)

Manodyzing. A process for the protection and decoration of magnesium and its alloys. A solution of phenol and water glass is used with anodic direct or alternating current, with the formation of a highly protective film of oxide silicate.

Manometer. A device for measuring gas pressures.

Manual Lincolnweld Machine. A portable electric welding unit, with automatic wire-feeding mechanism and equipment for feeding the granular flux on to the work. (See LINCOLNWELD.)

Mantle. (*a*) (See BLAST FURNACE.) (*b*) A covering of clay, destined to be used as a mould.

Mapping. (See VEINING.)

M.A.P.I. Machinery and Applied Physics Institute (U.S.A.).

M.A.R. An abbreviation for *micro-analytical reagent.*

Marbella. A Spanish magnetite with a siliceous gangue.

Marble's Reagent. An etchant for stainless steels, consisting of 4 grams of copper sulphate in 20 ml. hydrochloric acid and 20 ml. water.

Marcasite. (*White Iron Pyrites.*) A mineral consisting of sulphide of iron (FeS_2).

Marform Process. This consists in the application of a constantly and independently variable pressure to a pressure pad surrounding the punch or male die and gripping the blank, before and during pressing, between itself and the rubber matrix. It is claimed that this method of forming sheet steel parts renders it possible to form previously polished or coated material without impairing the appearance. (M. 105.)

Marino Process. A process of electrogalvanizing.

Mark Place. (See RECESS.)

Marked Bars. (See QUALITIES.)

Marking a Core. Shaping the core and its seat so that the core cannot be misplaced. (A. 26.)

Marl. A soft earthy deposit which may contain fragments of shells. It usually contains a considerable amount of clay and graduates into a calcareous clay.

Marmorized Fracture. A brittle fracture found in high speed steel which has not been fully annealed. (B. 118.)

Marquenching. (See MARTEMPERING.)

Marshall Richards' Back-pull Wire-drawing Machine. The main features of this machine are that the wire passes directly through the die from block to block, the block speed adjust-

ment is automatic, and any reduction of area may be used on any block. The die pull is directly indicated in pounds for each die. (L. 26.)

Martempering. (*Marquenching.*) In this method of heat treatment, the ideal is to quench the part at such a rate that it reaches the M_s temperature in the fully austenitic condition. After equalization of temperature, the part is cooled slowly, so that the temperature gradients are negligible and the resulting thermal stresses are at a minimum. In practice, this ideal is only approached in so far as it is necessary to prevent cracking, reduce distortion and obtain a given hardness. As the M_s point is usually in the region of 300° C., the quenching must be done in a salt or metal bath. This may introduce greater safety hazards than oil and produce a salt or metal film which must be removed. To obtain a sufficiently rapid quench, less scaling at the austenitizing temperature is allowable. The quenching and time available for the equalization of temperature, limits the section size that can be successfully martempered to somewhat less than that permissible with conventional quenching. Similarly the minimum carbon or alloy content for a given section is higher. The outstanding advantages of martempering are the prevention of cracking and the minimizing of distortion, these both resulting from the reduction of thermal stresses. (A. 3.)

Martenite. A synthetic fettling material, used for sintering open-hearth furnace bottoms. The approximate composition (variable) of martenite is: silica 5·2%, alumina 2·1%, ferric oxide 10·5%, lime 13·4%, magnesia 66·5% (ignition loss 2·3%). Martenite sinters more rapidly than magnesite, thereby reducing repair time and, moreover, it is suitable for hot patching. Martenite is as wear-resistant as magnesite, and has no deleterious effect on the slag. (K. 7.)

Martens, Adolf. (1850–1914.) A German metallurgist and pioneer metallographer. (S. 67.)

Martens' Ball Tester. An instrument for the determination of hardness by measuring the depth of impression. (H. 9.)

Martens' Hardness Tests. (*a*) ($P_{0.05}$). The load in kg. required to press a 5 mm. ball to a depth of 0·05 mm. below the original surface of the specimen. (*b*) Another method devised by Martens, which he designated the *scoring hardness* (H_2), determined the load on a 90° diamond cone required to scratch a width of 0·01 mm.

Martens' Sclerometer. The instrument developed by Martens in 1890 for the determination of the *scoring hardness*. (See MARTENS' HARDNESS TESTS.)

Martensite. A microconstituent of steel characterized by its acicular structure. Essentially a non-equilibrium condition of *alpha iron* formed directly from undercooled *austenite*. It is produced when steel is cooled very rapidly from the hardening temperature, i.e. at a speed greater than its critical cooling rate so that the transformation of austenite occurs at 400° C. or lower, according to the composition of the steel. It is the hardest of the decomposition products of austenite and is very brittle. (See Plates VIII (d) and IX (b).)

Martensite Range. The temperature interval between M_s and M_f.

Martin Bros. (See OPEN HEARTH FURNACE.)

Martin Process. (*a*) A method of forming a thin, protective aluminium-iron coating on steel or iron by treating it in an inert or reducing atmosphere containing aluminium chloride gas at a temperature of from 750° to 1100° C., the aluminium replacing the iron atom by atom. (S. 109.) (*b*) See PIG AND SCRAP and OPEN HEARTH PROCESS).

Martins-Siemens Steel. Steel made by the *Siemens* or *Open-Hearth Process*.

Martite. A mineral consisting essentially of *iron sesquioxide* (Fe_2O_3). It is distinguished from *magnetite* in that it has little or no influence on the magnetic needle.

Mascher Process. A modification of the *Reisert Process*, i.e. it is a casting-on process in which an intermediate zinc layer is used, except that in place of ordinary bronze, the bearing surface is formed of leaded bronze. (S. 31.)

Mash Resistance Welding. A welding process for steel sheets, which consists of limiting the amount of overlap to approximately 1½ times the sheet thickness and increasing the welding pressure to twice that required for conventional *seam welding*. It is claimed that the result is equivalent to a *butt-weld* in many types of steel, and that the necessity of grinding off flash is eliminated. (B. 117.)

Mason's Fatigue Testing Machine. An early type of fatigue machine for the application of repeated plane bending. A four-point loading system produced uniform bending moment over the whole length of the specimen. The two centre loads were applied by helical springs, and levers, acting as extensions of the specimen, were given reciprocating movements so that the loaded springs were just lifted off their seatings. The

A minor ore of manganese, usually found with other manganese minerals and iron.

Manganoferrite. (See FERROFERRITE.)

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Mann Tension Impact Testing Machine. A machine consisting of a pendulum for measuring the energy required to rupture the test specimen and a rotatable wheel to develop the necessary kinetic energy and velocity. The specimen and tup are attached to the pendulum. The wheel is brought up to the desired velocity and retractable horns are released striking the tup and thereby rupturing the specimen. (M. 72.)

Mannesmann Powder Process. A method for the production of metal powder in which molten iron containing about 4% of carbon is poured in a thin stream from a tundish so that it falls through the middle of an annular jet several inches in diameter. This jet is fed by high pressure air and is so designed that the air leaving the inside of the annular ring is directed downwards to form a vortex some distance below the ring. When the metal reaches this point it is rapidly disintegrated. The particles are roughly spherical in shape and have a highly oxidized skin with a high-carbon core. The powder is heated by passing it through a tunnel kiln in sealed containers, where the oxide skin is reduced by the carbon in the powder, yielding spongy hollow spheres. (M. 142.)

Mannesmann Tube Piercing Mill. A rolling mill for the production of seamless steel tubes. It consists of two double-conical rolls turning in the same direction. Each roll rotates at an angle to the workpiece with the centre lines of the roll shafts lying in parallel planes. A billet heated to the correct piercing temperature, 1100° to 1260° C., is pushed into the mill, where the rolls engage it and start the spinning action. Because the rolls are at an angle to the billet, the component of force in the longitudinal direction pulls the billet forward over the piercing point. As the billet travels forward between the rolls, it meets the piercing point which is placed at a fixed distance beyond the first point of roll contact. The metal immediately starts to flow around the piercing point, thus forming a tube at the average rate of one foot per second, the piercing point acting as an internal roll. (T. 26.)

Manodyzing. A process for the protection and decoration of magnesium and its alloys. A solution of phenol and water glass is used with anodic direct or alternating current, with the formation of a highly protective film of oxide silicate.

Manometer. A device for measuring gas pressures.

Manual Lincolnweld Machine. A portable electric welding unit, with automatic wire-feeding mechanism and equipment for feeding the granular flux on to the work. (See LINCOLNWELD.)

Mantle. (*a*) (See BLAST FURNACE.) (*b*) A covering of clay, destined to be used as a mould.

Mapping. (See VEINING.)

M.A.P.I. Machinery and Applied Physics Institute (U.S.A.).

M.A.R. An abbreviation for *micro-analytical reagent.*

Marbella. A Spanish magnetite with a siliceous gangue.

Marble's Reagent. An etchant for stainless steels, consisting of 4 grams of copper sulphate in 20 ml. hydrochloric acid and 20 ml. water.

Marcasite. (*White Iron Pyrites.*) A mineral consisting of sulphide of iron (FeS_2).

Marform Process. This consists in the application of a constantly and independently variable pressure to a pressure pad surrounding the punch or male die and gripping the blank, before and during pressing, between itself and the rubber matrix. It is claimed that this method of forming sheet steel parts renders it possible to form previously polished or coated material without impairing the appearance. (M. 105.)

Marino Process. A process of electrogalvanizing.

Mark Place. (See RECESS.)

Marked Bars. (See QUALITIES.)

Marking a Core. Shaping the core and its seat so that the core cannot be misplaced. (A. 26.)

Marl. A soft earthy deposit which may contain fragments of shells. It usually contains a considerable amount of clay and graduates into a calcareous clay.

Marmorized Fracture. A brittle fracture found in high speed steel which has not been fully annealed. (B. 118.)

Marquenching. (See MARTEMPERING.)

Marshall Richards' Back-pull Wiredrawing Machine. The main features of this machine are that the wire passes directly through the die from block to block, the block speed adjust-

ment is automatic, and any reduction of area may be used on any block. The die pull is directly indicated in pounds for each die. (L. 26.)

Martempering. (*Marquenching.*) In this method of heat treatment, the ideal is to quench the part at such a rate that it reaches the M_s temperature in the fully austenitic condition. After equalization of temperature, the part is cooled slowly, so that the temperature gradients are negligible and the resulting thermal stresses are at a minimum. In practice, this ideal is only approached in so far as it is necessary to prevent cracking, reduce distortion and obtain a given hardness. As the M_s point is usually in the region of 300° C., the quenching must be done in a salt or metal bath. This may introduce greater safety hazards than oil and produce a salt or metal film which must be removed. To obtain a sufficiently rapid quench, less scaling at the austenitizing temperature is allowable. The quenching and time available for the equalization of temperature, limits the section size that can be successfully martempered to somewhat less than that permissible with conventional quenching. Similarly the minimum carbon or alloy content for a given section is higher. The outstanding advantages of martempering are the prevention of cracking and the minimizing of distortion, these both resulting from the reduction of thermal stresses. (A. 3.)

Martenite. A synthetic fettling material, used for sintering open-hearth furnace bottoms. The approximate composition (variable) of martenite is: silica 5·2%, alumina 2·1%, ferric oxide 10·5%, lime 13·4%, magnesia 66·5% (ignition loss 2·3%). Martenite sinters more rapidly than magnesite, thereby reducing repair time and, moreover, it is suitable for hot patching. Martenite is as wear-resistant as magnesite, and has no deleterious effect on the slag. (K. 7.)

Martens, Adolf. (1850–1914.) A German metallurgist and pioneer metallographer. (S. 67.)

Martens' Ball Tester. An instrument for the determination of hardness by measuring the depth of impression. (H. 9.)

Martens' Hardness Tests. (*a*) ($P_{0.05}$). The load in kg. required to press a 5 mm. ball to a depth of 0·05 mm. below the original surface of the specimen. (*b*) Another method devised by Martens, which he designated the *scoring hardness* (H_s), determined the load on a 90° diamond cone required to scratch a width of 0·01 mm.

Martens' Sclerometer. The instrument developed by Martens in 1890 for the determination of the *scoring hardness*. (See MARTENS' HARDNESS TESTS.)

Martensite. A microconstituent of steel characterized by its acicular structure. Essentially a non-equilibrium condition of *alpha iron* formed directly from undercooled *austenite*. It is produced when steel is cooled very rapidly from the hardening temperature, i.e. at a speed greater than its critical cooling rate so that the transformation of austenite occurs at 400° C. or lower, according to the composition of the steel. It is the hardest of the decomposition products of austenite and is very brittle. (See Plates VIII (d) and IX (b).)

Martensite Range. The temperature interval between M_s and M_f.

Martin Bros. (See OPEN HEARTH FURNACE.)

Martin Process. (*a*) A method of forming a thin, protective aluminium-iron coating on steel or iron by treating it in an inert or reducing atmosphere containing aluminium chloride gas at a temperature of from 750° to 1100° C., the aluminium replacing the iron atom by atom. (S. 109.) (*b*) See PIG AND SCRAP and OPEN HEARTH PROCESS).

Martins-Siemens Steel. Steel made by the *Siemens* or *Open-Hearth Process*.

Martite. A mineral consisting essentially of *iron sesquioxide* (Fe_2O_3). It is distinguished from *magnetite* in that it has little or no influence on the magnetic needle.

Mascher Process. A modification of the *Reisert Process*, i.e. it is a casting-on process in which an intermediate zinc layer is used, except that in place of ordinary bronze, the bearing surface is formed of leaded bronze. (S. 31.)

Mash Resistance Welding. A welding process for steel sheets, which consists of limiting the amount of overlap to approximately 1½ times the sheet thickness and increasing the welding pressure to twice that required for conventional *seam welding*. It is claimed that the result is equivalent to a *butt-weld* in many types of steel, and that the necessity of grinding off flash is eliminated. (B. 117.)

Mason's Fatigue Testing Machine. An early type of fatigue machine for the application of repeated plane bending. A four-point loading system produced uniform bending moment over the whole length of the specimen. The two centre loads were applied by helical springs, and levers, acting as extensions of the specimen, were given reciprocating movements so that the loaded springs were just lifted off their seatings. The

speed of working of this machine was 200 reversals per minute.

Mass-Absorption Coefficient. (For X-rays in a substance.) The rate of decrease, per unit mass traversed of the natural logarithm of the intensity of a parallel beam; usually written μ/ρ. It is often more convenient than the absorption coefficient because its use does not require knowledge of the density ρ. (See also MASS-SCATTERING COEFFICIENT.) (A. 27.)

Mass Action Law. This law may be stated as follows: When a reversible reaction reaches a state of equilibrium, the quotient, found by dividing the product of the active masses on one side of the equation, by the product of the active masses on the other side, equals a constant. The quotient so found varies with temperature and pressure. In single-phase solution the active mass may be regarded as the *mol fraction* of a constituent in that phase.

Mass Effect. This term is commonly employed to signify the effect of size and shape during heat-treatment, but this is not strictly correct and may be misleading unless it is understood that it is the rate of cooling of a piece of steel which determines the properties resulting from a hardening or quenching process. The term is, therefore, correct only in the sense that a piece of steel 6 in. in diameter may be said to be more massive than one of the same length but only 3 in. in diameter. During a quenching process the former would obviously cool, over the same range of temperature, much more slowly. (See *Ruling Section*).

Mass Hardness. A condition in which the entire casting is excessively hard and unmachinable.

Mass-Scattering Coefficient. (For X-rays in a substance.) The rate of decrease, per unit mass traversed, of the natural logarithm of the intensity of a parallel beam, caused by scattering alone; usually written σ/ρ; the excess of the *mass-absorption coefficient*, μ/ρ over σ/ρ is called the true mass-absorption coefficient, μ'/ρ. (A. 27.)

MA Steel. A basic Bessemer steel produced in a side-blown converter. Five rows of 18 tuyeres (25 mm. diam. each) are arranged in the back of a converter without bottom tuyeres. It is claimed that the nitrogen content can be kept very low. Furthermore, excess of oxygen leads to a partial combustion of the carbon monoxide to dioxide, and, therefore, a high temperature of the steel. Bottom pouring can be carried through without difficulty. The quality of the steel is found to be equal to that of a good open-hearth steel but the blowing time is about twice that of a normal bottom blow, and the iron content of the slag increases by about 2%. (G. 7.)

Massenez Process. The method of desulphurization, described by Massenez in 1891, as in use at the *Hoerde* Works; in which high sulphur pig iron was poured whilst still molten into a mixer containing high manganese, low sulphur molten pig iron, with the result that a manganese sulphide slag was formed and the metal was desulphurized.

Mast. The term as used in connection with an electric arc furnace refers to a vertical standard which holds at right angles a supporting arm to which an electrode is clamped. (See Fig. 5.)

Master Alloy. (See HARDENERS.)

Master Block. A die block used to hold insert dies.

Master Pattern. A *pattern* embodying a special contraction allowance in its construction. It is used for making castings which are to be employed as patterns in production work.

Master Plate. A plate, drilled to receive either half of a split pattern, whose halves are different or are right and left handed.

Master Tool. A term applied to a tool which is used for checking the finish of work which does not require accurate gauging.

Match. An arrangement for obtaining a *parting* when moulding irregular patterns. Either a *sand match* or a more permanent *plaster match* may be used. For example, the latter may be made by making a small frame a little deeper than the exposed part of the pattern, fastening it to an extra *bottom board*, placing it on the *drag* with the pattern in place, and then filling the space with plaster of Paris poured through a hole previously made in the board. The pattern is greased to keep the plaster from sticking to it. (S. 139.)

Match Lines. (See MATCHED EDGES.)

Match Plate. A plate of metal or other material, on which *patterns*, split along the *parting line*, are mounted back to back with the *gating* system to form an integral piece. The operation of moulding is thus greatly facilitated. The match plate is placed between the parts of a flask and rammed from both sides; on removing the plate the parting is complete, and the use of an *odd side* dispensed with.

Matched Edges. (*Matched Faces, Match Lines.*) The machined surfaces of the dies at a parting plane at right angles to each other, from which all measurements are determined.

Matched Faces. (See MATCHED EDGES.)

Matched Parting. Forming a projection upon the *parting* surface of the *cope* half of the *pattern*, and a corresponding depression in the surface of the drag. (A. 26.)

Matching. The operation in *pack rolling* of placing parted sheets together to form a new pack in order that they can be so rolled that all the sheets in the pack are of the required gauge.

Material Utilization. That proportion of a batch of material bought in ingot, or semi-finished form, such as sheet or strip, which is actually converted into the finished product.

Matrix. As used in metallography the term applies to the principal constituent. It is the continuous phase of a polyphase alloy or mechanical mixture, i.e. the physically continuous metallic constituent in which the other constituents are embedded. (See METALLOGRAPHY.)

Matrix Metal. The American term for *matrix*.

Matsumura Indentation Hardness Test. A development of the Brinell test in which the load producing a definite depth of impression by a 4 mm. ball is measured. (M. 130.)

Matte. An impure metallic sulphide product obtained from the smelting of sulphide ores of metals such as copper, lead and nickel. (A. 27.)

Matte Surface. A dull, flat surface having low specular reflectivity.

Matthews, John A. (1872–1935.) Born at Washington, U.S.A. John A. Matthews took an important part in the development of permanent magnet and corrosion-resisting steels and in the use of vanadium in high speed steels. He was the first recipient of the Andrew Carnegie Gold Medal for Research.

Matthiessen's Rule. This states that, for a metal or alloy, the product of the electrical resistivity and its temperature coefficient is not affected by either deformation or the addition of small concentrations of solute atoms.

Mattson Shot Classifier. An apparatus for the rapid, visual determination of the size and distribution of closely sized particles, such as peening shot, cleaning shot and sand. It consists of two plane sheets of glass separated at the two vertical edges by accurately ground metal wedges. Particles dropped into the space between the glass plates lodge at a point where the effective diameter of the particle and the distance between the plates are the same. An additional feature of the apparatus is a sample splitter, which is needed to reduce the sample to a suitable size. (B. 59.)

Maximum Rake. (See RAKE.)

Maximum Rake Plan Angle. (See RAKE.)

Maximum Stress. (See TENSILE STRENGTH.)

Maxirolling. A rolling operation carried out in a specially designed forging press, which pre-forms the forging blanks, producing rapidly reduced sections, so that the stock is properly distributed to meet requirements. The maxiroll which effects this pre-forming, is an auxiliary attachment. It consists of a pair of reducing rolls mounted on the inside of the press frame, and thus occupying no usable die space. These rolls are driven by the press mechanism, and the roll-shafts are so designed that the rolls can be quickly changed to suit the requirements of the dies in use. (M. 33.)

Maxwell. The *c.g.s.* unit of *magnetic flux*. 1 maxwell equals 10^{-8} *webers*.

Maybach Impact Testing Machine. This apparatus is designed to make 60 to 80 impacts per second. The specimen, 9 mm. in diameter and 150 mm. in length, is subjected to dual impacts acting simultaneously in the same direction. The impacts are applied by means of two sets of cams spaced 70 mm. apart, each set of cams consisting of two rollers which are supported by suitable arms attached to a rotating shaft and which are arranged at 180° to each other. Following each impact, the specimen is rotated through 90°. The deflection is measured by means of a dial gauge in conjunction with headphones which make audible the contact between the gauge feeler and specimen. It is claimed that with this machine 10 million impacts can be completed in about 40 hours. Either notched or plain specimens can be used. (L. 9.)

M_b. In an investigation of the martensitic habit in single crystals of a 69% iron, 31% nickel alloy, it was observed that about 25% of the austenite transformed during subatmospheric cooling within the time-interval of an audible click. The shock wave sent out from the specimen was occasionally sufficiently intense to shatter the Dewar container. The temperature of the first burst of transformation, called M_b, occurs below M_s in these alloys. (M. 61.)

M.B.V. Process. (*Modified Bauer Vogel.*) A process of forming a thin oxide film by immersion in a solution containing chromates. Normally used in conjunction with paint, varnish or lacquer.

M.D.C. Mineral Development Committee.

Meaker Process. An *electrogalvanizing* process in which iron or steel articles are placed in a zinc sulphate bath, using

metallic zinc as a soluble *anode* and the objects to be plated as a *cathode*.

Measuray. An X-ray thickness gauge for strip steel in which the absorption of the strip is compared with that of specimens of standard thickness, the differences in output of two pick-up cells being amplified and indicated on a meter. (S. 124.)

Mecalix. An instrument for the determination of cutting force. It comprises a tool-holder which is movable with respect to its base, whilst a dynamometer arranged between the latter and the mobile holder is used for actual measurement of the cutting force. (M. 171.)

Mechanical Hysteresis Loss. (See DAMPING.)

Mechanical Joint. A joint made by mechanical means, and where welding is not employed.

Mechanical Metallurgy. The science concerned with the relationships among the measured mechanical properties of metals and their mechanical behaviour in service, and with the way these properties and service characteristics vary with chemical composition, structure and temperature. The field also includes mechanical processing such as *rolling* and *drawing*. (A. 27.)

Mechanical Pipe. An effect sometimes seen on sheared ends. It is caused by the combined effects of a dull shearing knife and a steel with a spongy centre. The knife tears the soft interior and leaves a hole which has the appearance of a pipe.

Mechanical Properties. Those properties which reveal the reaction of a material to an applied force and which are determined by mechanical means involving deformation and/or destruction. They include *tensile-*, *compression-*, *torsion-*, *bend-*, *hardness-*, *cupping-*, *impact-* and *fatigue-tests*. The properties vary considerably, not only with the composition of the material, but with the method of manufacture, mechanical working and heat-treatment.

Mechanical Refining. (See HAMMER REFINING.)

Mechanical Roughening. Deliberate roughening of a metal surface by sand blasting, sand rolling or pumicing in order to facilitate the adhesion of metal films, or other purposes.

Mechanical Strain Gauges. Instruments for the measurement of stress distribution; they indicate the deformation on a portion of the surface only. They are used for short duration static measurements where remote readings are not required.

Mechanical Testing. The methods by which the *mechanical properties* are determined.

Mechanical Twins. Lens-shaped or narrow band markings found in *body-centred cubic*, *close-packed hexagonal* and other crystal types (excepting the *face centred cubic*). These may be formed during plastic deformation by shearing movements of successive planes of atoms, resulting in a fixed and sudden change in orientation at the interface or twinning plane. (Cf. TWINNING.) (A. 27.)

Mechanical Working. Subjecting metal to pressure exerted, for example, by *rolls*, *presses* or *hammers*, to change its form or to affect the structure and, therefore, the *mechanical* and *physical properties*. (See also FORGING, ROLLING, EXTRUDING.)

Mechanics. The branch of physical science dealing with the behaviour of matter under the action of force.

Medart Straightener. A roller straightener that bends and straightens rods and tubes by means of a concave roll. (A. 27.)

Medium 8VO. (See BOOK SIZES.)

Meehanite. A trade name applied to certain pearlitic cast irons in which the molten metal has been treated with calcium silicide, resulting, it is claimed, in increased tensile strength. (See INOCULATED CAST IRONS.)

Meg. (See MEGA.)

Mega. (*Meg.*) A prefix denoting one million.

Megabarye. A unit of pressure equal to one million *dynes* per sq. cm.

Megacycle. The measure of frequency of high-frequency electric alternating current or oscillatory discharge. One million cycles.

Megalograph. A form of *camera lucida*.

Megascope. A modification of the magic lantern, used especially for throwing a magnified image of an opaque object on a screen, solar or artificial light being used.

Megavolts. One million volts.

Megawatt. A unit of electrical power equal to one million *watts*.

Megohm. The electrical unit of resistance equal to one million *ohms* and, therefore, used only for high resistance values.

Melanoscope. An instrument containing a combination of coloured glasses such that they transmit only red light, so that objects of other colours appear black, when seen through it. It is used for viewing coloured flames to detect the presence of elements such as potassium emitting red light.

Melanovanadinite. ($2CaO.3V_2O_5.2V_2O_4.6H_2O$.) A vanadium ore.

Mellozing. A process in which molten metal is sprayed by means of compressed air on to steel, wood, glass or other surfaces. The alloy or metal to be sprayed is first melted in a gas-fired crucible. It is then poured into a container forming part of the pistol, and is maintained in the molten state by a Bunsen-type burner which also preheats the compressed air. The latter issues from a nozzle conveying the liquid metal, by means of an annular space. When in use the pistol is tilted slightly downwards, so that the metal flows to the nozzle by gravity, where it is atomized and projected at a high velocity on to the parts to be treated. (E. 43.)

Melt. (*a*) To fuse or liquefy. (*b*) A *heat* or charge of steel or other metal or alloy.

Melting Hole. A gas, or more usually, coke, fired furnace used in the *crucible process*. (See Fig. 3.)

Melting House. (See CRUCIBLE PROCESS.)

Melting Loss. The loss of metal in a charge during the melting operation.

Melting Point. (*Fusion Point.*) The temperature at which a solid begins to liquefy. Pure metals, eutectics and some intermetallic constituents melt at constant temperature. Alloys generally melt over a range. (See also PYROMETRIC CONE EQUIVALENT.)

Melting Range. The range of temperature in which an alloy melts; that is, the range between solidus and liquidus temperatures. (A. 27.)

Melting Rate. (*a*) In welding, the weight or length of electrode melted in a unit of time. (*b*) The tonnage of metal melted per hour.

Melting Ratio. The proportion of the weight of metal to the weight of fuel used in melting. (A. 26.)

Melting and Refining Unit. A unit in which it is necessary both to melt the charge and also to effect some metallurgical change, so that the output is of a different chemical and structural quality from that of the metal charged.

Melting Unit. The term applied to a furnace in which melting is the essential requirement. In nearly all cases there is at least some incidental refinement.

Melting Zone. The region in the *cupola*, above the *tuyeres*, in which the iron is melted.

Menaccanite. (See ILMENITE.)

Mendeleef, Dmitri Ivanovitch. (1834–1907.) A Russian chemist who put forward the *periodic law*.

Menders. Tin plates having imperfections, but which can be recoated to form a prime or second quality sheet.

Meniscus. The curved surface of a liquid in a vessel. A liquid which wets the surface of the vessel, e.g. water, has a depressed meniscus; other liquids, e.g. mercury, have a raised or convex meniscus.

Mercast. A process whereby frozen mercury is employed for patterns for precision casting as an alternative to wax. Metals cast include aluminium and stainless steel, and tolerances of $\pm$ 0·003 in. on 1·5 in. can be readily maintained. The master mould, made of steel is first filled with acetone to displace air and lubricate the walls, after which mercury is poured in, expelling the acetone. The mould is then placed in a bath of methylene chloride maintained at $-60°$ C. by means of dry ice. The frozen pattern is subsequently removed, coated with a layer of cold refractory investment material, and hung up to dry in a cold atmosphere. After drying, the mould is cut open to expose the mercury so that the pattern melts and runs out. The mould is finally dried and fired before being placed in a cylindrical flask packed with investment material to provide support. The metal, which is melted in high-frequency furnaces, is cast in a centrifugal machine. (M. 38.)

Merchant Bar. (*a*) (*Merchant Iron.*) The finished form of *puddled bar* after *piling*, reheating and rolling. (*b*) In modern usage the term is applied to all hot rolled steel—sold from warehouses direct to the retail trade as a finished product.

Merchant Iron. (See MERCHANT BAR.)

Merchant Mill. (See ROLLING MILLS.)

Merchromizing. An extremely hard facing applied to the surfaces of such articles as valves; it is claimed that it provides resistance to corrosion and erosion at temperatures up to about 540° C.

Mercury. (*Hg.*) *Atomic weight* 200·61. *Atomic No.* 80, *Specific gravity* 13·56. *Melting point* $-38{\cdot}9°$ C. Silver-white metal, the only metal liquid at ordinary temperatures. It is used in scientific and electrical apparatus, etc., and as an alloy, in soft solders and dental alloys or amalgams, and also for patterns in precision casting. (See MERCAST.)

Merit Number. (See QUALITY VALUES.)

Merle Film Refining Process. A continuous process of steelmaking in which separately produced molten iron and a refining slag are simultaneously fed into a revolving refractory-lined chamber. The intimate mixing of the two materials and the fact that the contact surface is very large in proportion to the volume, cause the refining

reactions to take place exceedingly rapidly. The name film-refining is derived from the fact that the molten metal within the chamber at any given time forms a layer only about $\frac{1}{16}$ in. thick against the refractory lining. The rotary refiners are made in different sizes to produce from 1 to 3 tons of steel per minute. It is claimed that the method permits of much closer control than either Bessemer or open-hearth refining, and that it is more convenient to have the steel available continuously than in heats of 100 to 200 tons. (M. 95.)

Merlizing. A proprietary phosphate coating for application to steel surfaces.

Mesh Weld. A group of spot welds made by the resistance *spot welding* process where overlapping rods, wires or strips are welded together by the aid of contact points of relatively large area. (B. 105.)

Mesle's Chord. A method of estimating the thickness of a metal coating in which the coating is locally removed by means of a cylindrical grinding wheel of known radius in the case of a plane surface, or by a file if the surface is curved. The thickness of the coating is computed from the width of cut and the radius of the wheel or curved surface. Tests on coatings of known thickness show that the results are accurate to within about 10% for coatings at least 0·0002 in. thick; for thinner coatings the method is not sufficiently precise. (B. 66.)

Mesnager Impact Test. A test carried out on a *Charpy* impact machine, using a test piece 55 mm. in length × 10 × 10 mm. which has a U-shaped notch 2 mm. deep with a root radius of 1 mm.

Meta Bond. A zinc-iron phosphate coating for application to iron and steel.

Metahewettite. ($CaO.3V_2O_5.9H_2O$.) A vanadium ore.

Metal. An element that, as a rule, when untarnished, has lustre, is malleable, conducts heat and electricity. It can replace the hydrogen of an acid and so form a *base*. Except in very thinnest layers, it is opaque. Most metals are solid at ordinary temperatures, *mercury* being the exception, but at high temperatures most metals are fusible. Metals are electropositive and their atoms readily lose *electrons*. Commercially, *brass*, *Britannia metal*, etc., are called metals, but in the scientific sense they are alloys.

Metal-Arc Cutting. The severing of metals by melting with the heat of an arc produced between a metal electrode and the base metal.

Metal-Arc Welding. A general classification of a method of welding. It employs an electric arc and a mineral-coated consumable metallic electrode of a composition suitable to the steel to be welded. (See SHIELDED METAL-ARC WELDING, IMPREGNATED-TAPE METAL-ARC WELDING, SUBMERGED ARC WELDING, ATOMIC HYDROGEN WELDING, BARE METAL-ARC WELDING, INERT-GAS METAL-ARC WELDING, STUD WELDING, and SHIELDED STUD WELDING.)

Metal Ceramics. Materials composed of pure oxide ceramics and a metal constituent. They are usually fabricated by slip coating or powder metallurgy techniques and machining, and have physical and chemical properties not possessed by either constituent alone. (See CERAMALS.) (M. 21.)

Metal Cutting Fluids. There are essentially two important commercial types of cutting fluids: (1) Cutting oils, used neat at the machine, and (2) water-soluble oils or compounds, mixed with water to form an emulsion. Active mineral cutting oils are the most widely used in production machining. They may be made in several ways, depending upon the method of incorporating the chemically active constituents, which are usually either sulphur and/or chlorine, and sometimes small amounts of phosphorus. The most widely used soluble oil is a medium-viscosity mineral oil containing an emulsifier base or soap plus a coupling agent to form a homogeneous fluid. (B. 24.)

Metal Electrode. A filler- or non-filler-metal electrode, used in *arc welding*, consisting of a metal wire, with or without a covering or coating. (A. 37.)

Metal Electrode Arc Welding. A group of arc-welding processes wherein metal electrodes are used. (See SHIELDED METAL-ARC WELDING, IMPREGNATED-TAPE METAL-ARC WELDING, ATOMIC HYDROGEN WELDING, INERT-GAS METAL-ARC WELDING, SUBMERGED ARC WELDING, SHIELDED STUD WELDING, STUD WELDING and BARE METAL-ARC WELDING.) (A. 37.)

Metal Gathering. A development of normal *upsetting* methods which can be applied to an unsupported length of material. The component is subjected to electrical resistance heating in the zone where the metal flow is required. The temperature is held at plastic forging heat, the heated component being progressively displaced by the force of a hydraulic ram. This ram is arranged to feed continually the required amount of additional stock into the heated zone, so that the metal gradually heats to forging temperature and is

displaced as required into the "gathered" mass. (A. 3a.)

Metal Leaf. Extremely thin metal sheet.

Metal Penetration. A *casting* surface defect which appears as if the metal had filled the voids between the sand grains without displacing them. (A. 26.)

Metal Penetration Test. A casting is made 6 in. in diameter at the top and $5\frac{7}{8}$ in. in diameter at the bottom, the height depending on the ferrostatic pressure required on four test cores placed round the ingate. The relative resistance of these cores to metal penetration, all of which may be of different sand mixtures, may be measured by visual examination or by a microscope of low magnification. This test has been approved by the American Foundrymen's Society, Sand Division, as a tentative standard test. (G. 11.)

Metal Physics. A term used to describe the whole range of subjects associated with the structure, physical properties and theories of metals and alloys.

Metal Replacement. (*Immersion Coating* or *Plating*.) The deposition of a metal from a solution of its ions on a more anodic metal accompanied by solution of the latter metal.

Metal Spraying. (*Metallization.*) The process consists in melting the metal which is to be deposited, atomizing the molten metal by means of an air blast, and depositing the atomized metal upon the surface to be coated. A modern process for using liquid metal has been developed to accommodate 4 lb. of metal previously melted in a gas-heated crucible. The pistol in this case is rather heavy and the process, although limited to low melting metals, is said to be rapid in operation and to produce coatings of uniform character. The powder process of metal spraying consists in heating finely divided metallic powder to its melting point by blowing it through the flame of a blowpipe and projecting the resulting spray by an air blast. The process is limited commercially to metals of low melting point and, in particular, to zinc which can be obtained in powder form at a reasonable cost. (See also SCHOOP PROCESS.)

Metal Stitching. A quick method of joining thin-section metals and non-metals. Metal stitches have high shear and tensile strengths and are resistant to fatigue and vibration. They are formed from high tensile strength steel wire. The fact that they pierce their own holes as they are driven eliminates the pre-punching and drilling operations necessary when joining components by riveting. Stitching is distinguished from stapling in that with the latter process, pre-formed U-shaped staples are used, whereas a stitching machine automatically feeds wire from a coil, cuts it to length, forms a wire stitch, drives it through the material, and clinches it. (D. 16.)

Metal Wood. The name given to a structural element which is a combination of a metallic sheet with veneer or plywood; the latter are glued together under pressure at 140° C. The combination must be symmetrical, i.e. either metal between 2 veneer or veneer between 2 metal layers. The metal (iron, steel or light metals) must be completely degreased and the wood must be roughened with sand-paper in the fibre direction. The wood must contain 8% to 12% humidity as otherwise the film does not bind. The product is then dried at 20° to 25° in a chamber with 60% to 70% air humidity. Metal wood can be bent vertically to the gluing plane without coming apart, but it cannot be deformed in 3 planes (spherically). (R. 30.)

Metalastik. A process of bonding rubber and metal.

Metalayer Process. A molten-metal spraying method in which metal wire is fed into a pistol; it is melted by a small oxy-acetylene flame, and is then blown on to the object to be coated by compressed air. The coating cannot be separated from the object by severe hammering or bending, and oxidation is prevented by using a reducing flame in the pistol. (M. 22.)

Metalclad Fusion Cutter. A machine designed to cut $1\frac{3}{8}$ in. thick armour plate at 3 in./minute. The machine operates on the principle that if a band is run at a high speed and a steady pressure is exerted on the material to be cut, intense heat is generated in front of the cutting edge, which plasticizes the material at this point and so permits rapid cutting. (M. 53.)

Metalcote 516. A zinc-iron phosphate coating for use on iron and steel.

Metalcote 628. A manganese-iron phosphate coating for use on iron and steel.

Metallic Binding Forces. The attraction of the positive ions constituting metallic crystals for the negative electrons that form a gas permeating the structure. This attraction holds the structure together and balances the repulsive forces of the ions for one another and electrons for other electrons. The electrons move freely through the lattice and provide good thermal and electrical conductivity. (A. 27.)

Metallic Soap. (See SOAP LUBRICANTS.)

Metallization. (See METAL SPRAYING.)

Metallochromes. The coloured effects, due to interference, produced on polished metals, especially iron and nickel, by the electrodeposition of films of varying thickness, usually of lead peroxide.

Metallography. The branch of science which deals with the study of the structure and constitution of solid metals and alloys, and the relation of this to properties on the one hand and manufacture and treatment on the other.

Metalloid. (*a*) An element possessing both metallic and non-metallic properties, i.e. the physical properties of metals and the chemical properties of non-metals, e.g. arsenic. (*b*) The term is sometimes applied to the elements commonly present in small amounts in steel, e.g. carbon, silicon, manganese, sulphur and phosphorus.

Metallurgical Notch. Any narrow region within a piece of metal where considerable changes in hardness occur. (B. 122.)

Metallurgy. Art and science applied to metals. The term covers extraction from ores, refining, alloying, shaping, treating, and the study of structure, constitution and properties.

Metallurgy of Powders. The term is applied to all those uses of powder, such as *spraying, calorizing, sherardizing*, etc., to certain solders, and to reduction processes of the thermit type. (Cf. POWDER METALLURGY.)

Metalock. A method for the cold repair of *castings* and *forgings*. The principle of the method is to drive a number of specially shaped key elements transversely across the crack of a damaged part. The keys are made of a series of high nickel alloys. (I. 69.)

Metalometer. A precision hardness tester whose special features include a trigger release mechanism, with an anvil attachment, which is claimed to broaden the application of testing the surface hardness of small parts. (M. 86.)

Metals Comparator. An instrument for testing metal and non-metallic parts by magnetic methods and comparing them with standard materials. The oscillator can supply current to the test coil at frequencies of 50, 250, 500, 1000, 2500, 4000 and 10,000 cycles/sec. (B. 71.)

Metalsorter. (See TRIBO-ELECTRIC SORTING.)

Metamic. A metal ceramic consisting of high Cr-Al_2O_3.

Metamorphism. Chemical and physical changes occurring in igneous and sedimentary rocks produced by interaction together with heat and pressure.

Metarals. A term suggested by Howe for true phases, i.e. definite chemical compounds or solid solutions. He suggested dividing all microscopical constituents of iron and steel into metarals and *aggregates*. Thus, *ferrite, cementite, austenite* and *graphite* would be classed as metarals, whilst the aggregates would include *pearlite, sorbite, troostite, ledeburite*, and *steadite*.

Metarossite. ($CaV_2O_6.2H_2O$.) A vanadium ore.

Metastable. A condition of comparative instability which passes into a stable phase under certain conditions, e.g. the condition of a melt when cooled below the *true freezing point* where crystals will form in the presence of suitable nuclei but in which, in the absence of such nuclei, crystallization does not commence until the melt enters the *labile range*.

Metatectic. (See PERITECTOID REACTION.)

Metco Method of Shaft Preparation. A method of roughening the surface of a metal prior to metal spraying. A groove or thread is cut with a round-nosed tool and thereafter the ridges are spread over by using the shaft preparation tool. Although this method can only be employed on machinable materials, it does provide a means of producing uniform and reliable bonds over a wide range of machine element work. (S. 138.)

Metcolizing. A method developed for the economical and efficient protection of iron and steel against oxidation and scaling at elevated temperatures in corrosive atmospheres. It is also recommended for the protection of nickel and nickel-chrome alloys against attack by sulphurous gases. Basically, the processes involve the coating of steel with pure, metallized chromium-nickel alloy, and/or aluminium, and special sealers. There are three metcolizing processes, each recommended for use on equipment subjected to a particular range of temperatures, service conditions, and other factors.

Meteoric Iron. The only form in which iron is found native. It varies in composition, but is usually alloyed with an appreciable amount of nickel, ranging up to 20%.

Method X. A cutting method developed to facilitate the machining of any electrically conductive material, regardless of its hardness. The process involves the shaping of metallic parts by an electric spark discharge of controlled intensity and duration and is not to be confused with other developments for the machining of *hard metals*, such as the use of the arc effect to remove

metal by thermal action, or the vibration of tools at a supersonic frequency in a liquid suspension of abrasives. The action of the Method X machine depends on a mechanical rather than thermal effect of electricity which sets up internal mechanical stresses by the use of extremely high current densities and thus causes the metal particles to detach themselves from the work material without resort to melting. (E. 32.)

Methods Time Measurement. An American procedure for systematic work simplification.

Methyl Orange. A sodium salt of para-sulpho-benzene-azodimethyl-aniline. It is used as an indicator in alkalimetry, i.e. it gives a pink colouration in the presence of free acid and remains yellow in alkaline solutions.

Metlbond. A process of joining metal parts by means of a metal adhesive instead of by riveting or welding. After cleaning, one or two coats of cement are sprayed on all surfaces to be bonded and allowed to dry for between 20 min. and 2 hrs. Metlbond tape is applied to one of the mating surfaces and the parts are assembled, using a special fixture when larger quantities are involved. Assembled parts, protected from contamination and dust, must be cured within 72 hrs. The entire area to be bonded is clamped under a pressure of 75 to 100 lb. per sq. in. (H. 54.)

Met-L-Chek. (See DYE PENETRANT.)

Metre. The unit of length in the metric system. The length of the International Prototype Metre (kept in Paris) = 39·37 in.

Metre Ton. (*Metric Ton.*) 1000 kilograms (approximately 2205 lb.).

Metric System of Weights and Measures. (See Appendix II.)

Metric Ton. (See METRE TON.)

Metrical Calorie. (See CALORIE.)

Metrochrome. An instrument for measuring colours.

Metroflux Test. A method of non-destructive testing of spot welds in stainless steels, using a captive-fluid magnetic cell. This cell consists of a transparent plastic moulding, which can be of any convenient size or shape, in the form of a shallow dish with a thin diaphragm forming a back that is usually opaque and white. The cell is sealed off and contains a small quantity of black magnetic fluid made up of minute magnetized particles suspended in a light oil. If such a detector is shaken well so as to disperse the magnetic particles through the oil and is laid down on the magnetized sheet face containing a spot weld, the magnetic particles will swim to the magnetic spot and reveal it as a particle pattern on the white diaphragm. This will only occur if the magnetic properties at the spot differ appreciably from those of the parent sheet. Thus the detector only shows up those spots that have reached a high enough temperature during welding to produce satisfactory welds. (A. 40.)

Metrology. The theory and practice of precision measurement in the field of mechanical engineering.

Mev. Symbol for million electron volt.

Meyer Hardness Test. This may be summarized in the following expressions:

$$L = ad^{n} \qquad (1)$$

$$M = \frac{L}{\pi d^2/4} \qquad (2)$$

where

- L = load in kilograms (usually on a 10 mm. ball),
- d = diameter of indentation in millimetres,
- M = Meyer hardness in kilograms per square millimetre of projected area,
- a = pre-test hardness in kilograms per square millimetre of projected area, and,
- n = coefficient representing strain hardenability.

(H. 52.)

M_f. (See TRANSFORMATION TEMPERATURE.)

Mg. Chemical symbol for *magnesium*.

mg. Abbreviation for *milligram*.

MgO. Chemical formula for magnesia.

MgO_2. Chemical formula for magnesium peroxide.

Mho. The practical unit of electrical conductance, being the conductance of a body having an electrical resistance of 1 *ohm*. It is the reciprocal of resistance.

μ Inch. (See MICRO INCH.)

Mica. An alkali aluminium silicate of variable composition, e.g. *muscovite* and *phlogopite*. It is transparent and an efficient heat insulator and is used in the electrical industries as an electrical insulator, and for windows in various types of heating equipment. It is prepared by splitting along the natural cleavage lines by hand, larger sheets being made up from these splittings by bonding with varnish or other adhesives. (W. 48.)

Micacid Insulating Process. A process for insulating electrical sheets, in which they are covered with a mixture of strongly acid phosphate solution and powdered mica, using rubber rollers. It is claimed that insulation and corrosion

protection are accomplished in a single operation, keeping the cost of the process very low, no pre- or post-treatment being required. (W. 77.)

Mica Schist. A type of rock, used in certain districts for refractory linings of furnaces, cupolas, etc.

Michelson Interferometer. A device for calibrating finely divided scales, strain gauges, precision dial indicators, and other length-measuring equipment, using the wave-length of light as the unit of measurement. (R. 17.)

Micro. A prefix from the Greek mikros," meaning small.

Microanalysis. The determination of chemical composition where the quantities involved are of the order of not more than one-tenth of those measured by the usual analytical methods.

Microanalytical Reagent. (*M.A.R.*) A standard of purity which indicates that a reagent is suitable for *microanalysis*.

Microbalance. An extremely sensitive balance for very accurate work.

Micro-Burette. A burette, designed to deliver drops of approximately 0·01 millilitre. (R. 16.)

Microcast Process. A precision investment casting technique originated for the casting of non-machinable alloys.

Microcharacter Hardness Tester. (*Bierbaum's Standard Instrument.*) An instrument for determining the scratch hardness of microscopic areas, and designed for attaching directly on to the stage of a metallurgical microscope and operating thereon. The microcharacter consists of a balanced arm to which is attached a diamond pointed tool which rests directly on the surface of the specimen to be tested, and is mounted under a very light load. The width of the scratch produced by the diamond is measured under the microscope.

Microchemistry. A chemical technique involving extremely sensitive reactions and measuring devices as in *microanalysis*.

Microcleanness. The extent or quantity of non-metallic inclusions observed by examination under a microscope.

Microconstituents. The components of a microstructure observed in a polished and etched specimen when viewed under a microscope, e.g. *ferrite*, *pearlite*, *austenite*, and *martensite*. (See Plates VII, VIII, IX and X.)

Microcosmic Salt. Sodium ammonium hydrogen phosphate.

Microdurometer. A machine designed for measuring the hardness of very thin specimens of metal, e.g. cartridge cases. The impression-ball is held in a cone at the lower end of a vertical shaft to which the axial load can be applied gently by means of a weighted beam. The slight motion of the shaft actuates an arm carrying a mirror system, which enables small indentations of the specimen placed on the platform beneath the ball to be read off by a spot of light on a scale. (E. 83.)

Micro-Etching. *Etching* of samples for examination under the microscope.

Microfarad. One-millionth of a *farad*.

Microformer. A type of extensometer used for the measurement of the elongation of the test piece in a tensile test. In this instrument the extension of the test piece produces a movement of an iron core in a small magnetic coil, thus changing its *inductance*. The recorder contains a similar magnetic coil which is automatically kept in balance by a servometer which also controls the recorder.

Microgram. One thousandth of a milligram or one millionth of a gram.

Micrograph. A graphic reproduction of any object magnified more than 10 diameters (usually 200 or more). When it is desired to indicate that it is a photographic reproduction, the term *photomicrograph* may be employed. (A. 28.)

Micrography. The study of metal structures under the microscope.

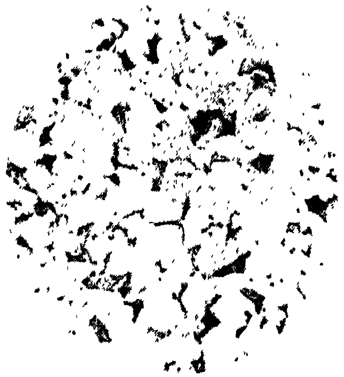
Micro-Hardness. Hardness determined by the use of very low loads and diamond pyramid indenters. It is claimed that by means of specially developed instruments it is possible to measure impressions with width of the order of the *micron*, e.g. it enables the hardness of micro constituents to be determined. (See also MICROCHARACTER, KNOOP HARDNESS, TUKON TESTER, etc.)

Microhm. The electrical unit of resistance, equal to one millionth of an *ohm*.

Micro Inch. (μ *Inch.*) One millionth of an inch.

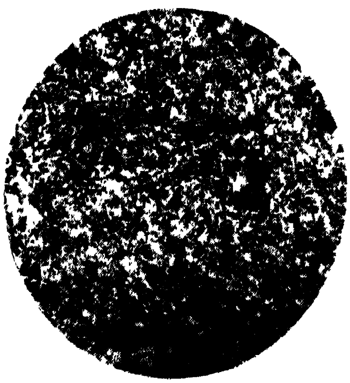
Micro-Indentation Hardness Testing Instruments. These instruments are of widely different types, their essential characteristic being the use of a very low load which may vary between 0·1 to 500 g. but is usually between 1 and 200 g., the load being applied by means of weights or by calibrated springs. The object of indenting under such a low load is to produce an impression of such precision and minute dimensions that it can be contained within the area of a single phase.

Micromanometer. A sensitive device for measuring gas pressures in the 0 to 150 *micron* range. It measures the absolute pressures of condensible as well as non-condensible gases independently of their composition. The operation is based on a pressure sensitive condenser,



a) 0.11% Carbon steel—etched × 200 (Normalized)
Hypoeutectoid steel showing some areas of pearlite on background of ferrite.

(b) 0.33% Carbon steel—etched × 200 (Normalized)
Hypoeutectoid steel showing ferrite and pearlite.



(c) 0.83% Carbon steel—etched × 200 (Normalized)
Eutectoid steel, i.e. the whole structure consists of pearlite.

(d) 1.2% Carbon steel—etched × 200 (Normalized)
Hypereutectoid steel showing pearlite with excess cementite at grain boundaries and across grains.

(Reproduced by courtesy of the Brown-Firth Research Laboratories.)

Plate VII.—Effect of Carbon Content on the Microstructure of Plain Carbon Steel.

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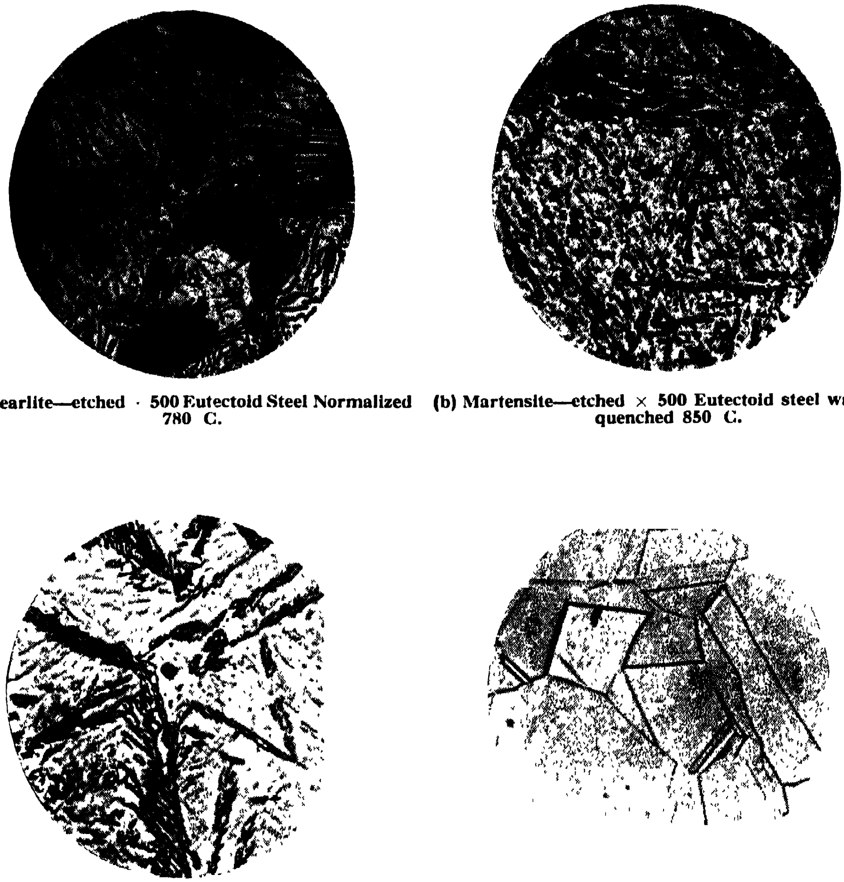


(a) Pearlite—etched × 500 Eutectoid Steel Normalized 780 C.

(b) Martensite—etched × 500 Eutectoid steel water quenched 850 C.

(c) Bainite in 3% Cr-Mo Steel Heated 1200° C. for 15 minutes. Quenched to 400° C.—maintained at 400° C for 24 hours then water quenched—etched × 1250.

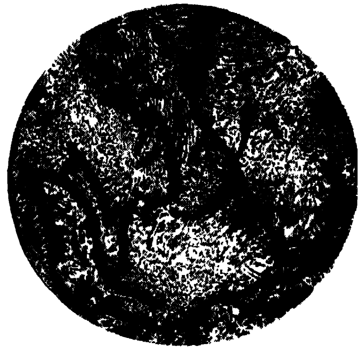
(d) Twinned Austenitic Structure of cold worked Cr-Ni 18/8 type corrosion resisting steel—etched × 500.

(Reproduced by courtesy of the Brown-Firth Research Laboratories.)

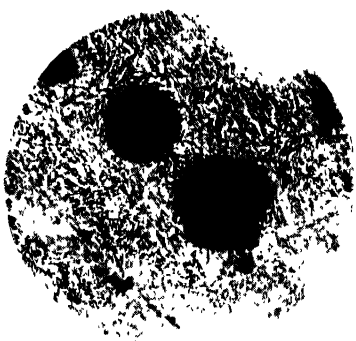
Plate IX.—Typical Microconstituents of Steel.

To follow plate viii

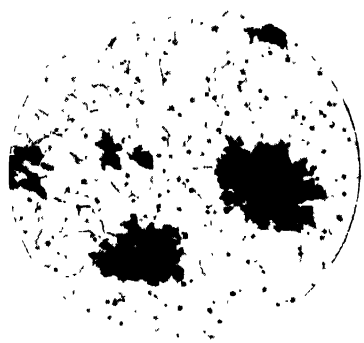
(a) White Cast Iron—etched × 100.
Primary precipitation of austenite with ledeburite eutectic. The austenite has subsequently broken down into pearlite and cementite.



(b) Grey Cast Iron—etched × 200.
Showing flakes of graphite in matrix of pearlite.



(c) Spheroidal Cast Iron—etched × 200.
So called after the form of the graphite.



(d) Malleablized Cast Iron—etched × 200.
Showing rosettes of graphite against a background of ferrite. (Black-Heart Process.)

(*Reproduced by courtesy of the Brown-Firth Research Laboratories.*)

Plate X. Microstructures of Some Typical Cast Irons.

To follow plate IX

utilizing a stainless steel diaphragm as one of the plates; the gauge forms one arm of a capacitance bridge which is balanced to a null when the pressures on each side of the diaphragm are equal and close to zero microns. In operation, the gas whose pressure is to be measured is introduced to one side of the diaphragm, and an electrostatic restoring force is applied by an adjustable D.C. voltage, thereby rebalancing the bridge. The magnitude of the restoring voltage is read on a duodial and the reading is converted to microns of pressure by a calibration chart or simple formula. (R. 18.)

Micromaster. A micrometer capable of measuring accurately 0·001 millimetre over a range from zero to 25 mm. Hundredths of a millimetre can be observed through a window and thousandths can be read off the vernier scale, while the number of millimetres is shown on the barrel. (E. 74.)

Micromet. Sodium calcium hexametaphosphate. A corrosion inhibitor used for the treatment of water.

Micrometer. A precision measuring instrument equipped with a screw of fine graduations showing very minute movements of the screw.

Micro-Micron. ($\mu\,\mu$.) One-millionth of a *micron*.

Micro Pipes. Tiny cavities, a fraction of a millimetre in size, with irregular and ragged outlines and with non-oxidized walls, which occur in castings. Etching shows that they occur at the intersection of convergent dendritic directions. (P. 36.)

Micron. A unit of length equal to a millionth of a metre (0·001 mm.), 0·000039 in. It is used for expressing minute distances or wave-lengths of light and is denoted by the Greek letter μ.

Microporosity. Extremely fine porosity caused in castings by shrinkage or gas evolution and apparent on radiographic films as mottling. (A. 27.)

Microradiography. The process of passing X-rays through a thin section of an alloy in contact with photographic emulsion and then magnifying the *radiograph* 50 to 100 times to observe the distribution of alloying constituents. (A. 26.)

Micro-Sclerometer. A micro-hardness tester designed for use on metallurgical microscopes. Having chosen visually a suitable area for the impression, the operator replaces the microscope objective by the micro-sclerometer, without displacing the specimen. The microscope stage with the specimen is then lowered into the spring-loaded diamond indenter. The axial displacement of the indenter which is measured by optical means is indicative of the load exerted. After raising the stage, the micro-sclerometer is replaced by a high-power objective, by the aid of which the dimensions of the impression can be measured. (G. 24.)

Microscopy. The study and examination of matter by means of a microscope.

Microsection. A metal specimen whose surface has been polished and etched to reveal the microstructure.

Microspectroscopy. A method of identifying metallic constituents; it consists of drilling out the minute portion to be analysed, flowing collodion over the resulting chips, and transferring the collodion together with the chips to a pure-carbon electrode for analysis in a standard spectrographic arc.

Microstresses. (*Heyn Stresses.*) Stresses that are balanced over distances of the order of magnitude of grain diameters.

Microstructural Change. The alteration in solid metals or alloys involving modification of the microstructure. It is usually associated with constitutional changes, but may occur independently of these, as for example, when crystals are deformed by working of the metal or when deformed crystals recrystallize.

Microstructure. The detailed structure of a metal or alloy, as developed by suitable polishing and etching, and revealed by examination under the microscope at a magnification of not less than 10 diameters, and usually much greater. The microstructure shows the different phases making up the material, together with any non-metallic inclusions which may be present. (See Plates VII, VIII, IX, and X.)

Microtome. An instrument for cutting thin sections of specimens.

Microton. A mechanical stage designed for use with the *Tukon hardness tester*, which enables an area of a few thousandths of a square millimetre to be accurately located under the microscope. The specimen is moved under the indenter, the indentation made on the selected area and the specimen returned under the microscope for the purpose of reading the dimensions of the impression, which is within less than 10 microns of the desired area.

Micro Welds. Minute welds or adhesions formed at isolated areas of true contact by dry friction, as for example, between piston rings and cylinder walls during the running in of an internal combustion engine. (S. 146.)

Middle Half of Gauge Length. The half gauge length situated on either side of the central point of the tensile test piece.

Middling. The first stage in drawing a hollow forging to the required diameter and length, after the trepanned bore of the ingot has been expanded to take a mandrel corresponding to the bore diameter of the finished forging.

Middlings. Products of specific gravity, intermediate between that of the *concentrate* and the *tailings*, obtained in the jigging of crushed ores which, recrushed to a finer size, are then re-treated to obtain a concentrate.

Mig. *Metal Inert Gas Welding Process.* (See SIGMA WELDING.)

Migra Iron. A special pig iron for high quality castings, made by subjecting the molten pig from the blast furnace to a thermal treatment based on the principle of superheating. (P. 24.)

Mikro-Testor. A low load hardness tester, suitable both for Vickers and Knoop tests working with loads of between 10 to 3000 g. The load is applied through a balanced lever with equal arms. An adjustable oil brake ensures smooth load application. The load is applied from below against the object under test, which is held in a suitable mounting. The impression is measured with a built-in measuring microscope which gives an enlargement of 500. A simple lever movement switches over to observation on a screen (200 enlargement). A small hand lever can turn the image through 90°, so that both diagonals of the impression can be measured without moving the object under test or the measuring unit.

Mil. One thousandth of an inch. A *circular mil* is a unit of area which is equal to the area of a circle having a diameter of one mil.

MIL. Prefix for U.S.A. Military Specification.

Mil Foot. An American term for a wire length of one foot with a diameter of one mil. (One mil = 0·001 inch.)

Mild Drawn Wire. (*Soft Drawn Wire.*) Wire which has undergone a reduction of area not greater than 10%, in drawing from the original rod.

Mild Steel. Plain carbon steel containing about 0·10% to 0·20% carbon.

Mill. (*a*) (See ROLLING MILLS). (*b*) The term as used in the U.S.A. may refer to a plant for comminuting and concentrating ore. (*c*) Any building fitted with machinery for manufacturing processes. (*d*) To produce regular markings on the edge of a coin. (*e*) In the U.S.A., one thousandth of a dollar. (See also MILLING.)

Mill Coil. The product of a single *billet* or *slab* in the form of narrow hot rolled *strip*.

Mill Edge. (*Band Edge.*) The edge obtained on sheet or strip when it has been rolled on the flat surface only. (See EDGE.)

Mill Finish. A surface finish produced on sheet and plate, characteristic of the ground finish on the rolls used in fabrication. (A. 27.)

Mill Furnace. A small *reverberatory furnace* for heating piles of *puddled bar* to welding heat.

Mill Furnace Cinder. (*Flue Cinder, Flue Slag.*) Cinder obtained from the flue of a reheating furnace.

Mill Hardening. Direct heat treatment from the rolling mill or forge. The forged or rolled product is allowed to obtain uniformity of temperature throughout the section by transferring to a soaking pit from which it is subsequently oil- or water-quenched.

Mill Length. Those lengths which can be most economically handled by the mill. Upper and lower limits are set by equipment limitations in the mill.

Mill Pack. The product of *ply* or *pack* rolling.

Mill Pile. (See PILING.)

Mill Scale. Iron oxide scale formed on the surface of steel during hot working processes.

Millscale Method of Selective Carburizing. A method of preventing the carburization of the surface of the bore of gear wheels. A convenient number of the gears are stacked on a long bolt provided at each end with a washer larger than the diameter of the base. The inside of the assembly is filled up with millscale before tightening the nut on the top washer. The stack of gears is then placed in the gas-carburizing furnace. (S. 37.)

Mill Shearing. Cutting a *mill pack* to size.

Mill Spring. In a rolling mill, the total looseness under load of all mechanical parts between the *roll necks* and the *housings*.

Miller Indices. (See CRYSTAL INDICES.)

Millerite. A mineral consisting of nickel sulphide (NiS).

Milli. A prefix signifying the one-thousandth part.

Milligram. One thousandth of a gram. ·0154 grain.

Millilitre. One thousandth of a litre.

Millimetre. One thousandth of a metre.

Milling. (*a*) A process of machining in which metal is removed by a revolving multiple-tooth cutter, to produce flat or profiled surfaces, grooves and slots. (*b*) In *powder metallurgy*, the mechanical treatment of material, as in a ball mill,

to produce particles or alter their size or shape, or to coat one component of a powder mixture with another. (*c*) The operation of crushing and grinding ore. (See MILL.)

Milling and Tempering. The thorough mixing of sand with a binder, either natural or added in the presence of a lubricant or other fluid, usually water. The operation is normally carried out in edge runner mills with the runners raised from the pan so as to produce a kneading rather than a grinding action.

Milliscope. An instrument which gives electrical warning when the steel which is being heated reaches a predetermined temperature. It can also be adapted to give rapid automatic control of heater movement, via an oil servo-mechanism, to give uniform heating of any component. (M. 115.)

Minasragrite. ($V_2O_4.3SO_316H_2O$.) A vanadium ore.

Mineral. An inorganic element or compound occurring naturally in the earth's crust, e.g. *haematite* and *gold*.

Mineral Acids. The common inorganic acids, e.g. nitric, hydrochloric, sulphuric and phosphoric acids.

Mineral Blacking. (See BLACKING.)

Mineral Wool. A generic term covering a number of products among which is included *slag wool*. It consists essentially of slag from the blast furnace, through which steam has been blown. (T. 14.)

Mineralogy. The study of minerals and rocks.

Minette. An oolitic *limonite*, consisting of $2Fe_2O_3.3H_2O$. Although a low-grade siliceous ore, it constitutes one of the most important iron ore deposits of Europe and it occurs in large quantities in the *Minette Basin*.

Minette Basin. The source of *minette* ore, i.e. Lorraine, Luxembourg, Belgium and Northern France.

Miniature Reeve Test. (See REEVE WELD CRACKING TEST.)

Minium. *Red Lead*.

Ministry of Materials. Horse Guards Avenue, London, S.W.1. Formed in July, 1951, to take over responsibility for the supply of non-ferrous and light metals in unwrought forms (with certain exceptions), sulphuric acid, natural and synthetic rubber, paper, etc.

Minus Mesh. In *powder metallurgy*, the portion of a powder sample that passes through a screen of stated size. (A. 27.)

Minute. (*a*) Measure of an angle; $\frac{1}{60}$ of a degree, 60 seconds. (*b*) Measure of time; $\frac{1}{60}$ of an hour, 60 seconds.

M.I.R.A. Motor Industry Research Association.

Mirror Galvanometer. (*Reflecting Galvanometer*.) A *galvanometer* having a mirror attached to the moving part, so that the deflection can be observed by directing a beam of light on to the mirror and observing the movement of the reflection over a suitable scale.

Mirror Image. The image of an object as viewed in a mirror.

Misch Metal. An alloy containing about 50% cerium with 50% lanthanum, neodymium and similar elements. On the addition of about 35% iron to such an alloy, a highly pyrophoric alloy is produced which is used in the production of cigarette lighters, etc.

Miscible. *Soluble*.

Miscibility. The mutual solubility of two or more substances.

Mishima Magnet Steel. (*MK Steel*.) A powerful magnet steel, developed by T. Mishima. It has a high *residual magnetism* and a magnetic intensity of more than twice that of high cobalt magnets. It is resistant to oxidation and has a low specific gravity, having a typical composition of 10% aluminium, 25% nickel, balance iron (British Patent No. 392,658.)

Mismatch. A defect sometimes found in drop *forgings*. It is caused by the misalignment of the impressions in the top and bottom *dies*.

Mispickel. Arsenical iron ore.

Misruns. Defects in castings where the metal has failed perfectly to reproduce the mould contours.

M.I.T. Massachusetts Institute of Technology.

M.I.T. Slow Bend Test. A test developed to compare the temperatures of transition to brittle fractures, in which a specimen of any shape is supported as desired and loaded at a predetermined constant rate with an accurate control of the testing temperature. In this manner, it is possible to vary the constraint, the strain rate and the testing temperature so that the separate effects of these variables can be controlled and measured. The strain rate can be maintained constant throughout the test which is not possible in the standard Charpy test. The equipment loads a specimen at a uniform speed under a constant temperature and a load-deflection record is made for each test. Electric strain gauges connected into a bridge circuit measure both load and deflection. The integral parts of the equipment include a loading machine with strain gauges, a thermocouple, and a millivoltmeter, stop watch, electronic recorder and a still camera. The loading device employs a lever system which transmits the load to the specimen which rests

on a suitable support. The support, specimen and electric strain gauges are housed in a sub-zero test cabinet which can be cooled to $-73°$ C. or lower. (M. 7.)

M.I.T. Whirl Pit. A whirl pit installed by the Massachusetts Institute of Technology, in which steel discs, plain and welded, are rotated in a partial vacuum at speeds up to 12,000 r.p.m. by a steam turbine. By this means, plastic flow and fracture properties can be studied, and it is claimed that this method of investigation has great advantages over hydraulic bursting tests, in that the ratio of the radial and tangential stresses remains nearly constant, up to fracture. (M. 8.)

Mitis Castings. Castings of very mild steel.

Mitsche-Reichert Eyepiece. The eyepiece of a metallurgical microscope, carrying a glass disc with a series of seven hexagonal *graticules*, of different dimensions. The disc can be turned so as to bring the graticule of the desired size to cover the image, and thus the grain size, and the quantity and distribution of slag inclusions, can be rapidly determined. (M. 144.)

Mixed Acids. A general term for mixtures of two or more acids.

Mixed Blast Process. A modification of the *basic Bessemer process* in which all the nitrogen is removed from the blast, the blast being made up of a mixture of oxygen and carbon-dioxide or oxygen and superheated steam. The oxygen and superheated steam blast is claimed to be the more efficient, the final nitrogen content of the metal being brought to a mean level of 0·0028%. (B. 79a.)

Mixed Crystals. An obsolete term synonymous with *solid solutions*. It refers to a homogeneous solution of two or more crystallized bodies in the solid state and does not include mechanical mixtures of different substances.

Mixed Welding. The practice of making most of the weld with carbon steel electrodes and finishing with stainless or other high alloy steel.

Mixer. A large furnace used as a reservoir for molten pig iron coming from the *blast furnace*. The product of several furnaces is thus mixed, and the composition can be regulated by making suitable additions. It is used in connection with hot metal steelmaking and direct casting of pig iron.

Mixer Metal. Molten iron from the blast furnace which has been kept in a *mixer* prior to transferring to the *open hearth* for the *hot metal process*, or to the Bessemer furnace.

Mixing. In powder metallurgy, the thorough intermingling of powders of two or more substances. (A. 27.)

Mixing Chamber. That part of a gas-welding or oxygen-cutting torch wherein the gases are mixed. (A. 37.)

M. K. Steel. (See MISHIMA MAGNET STEEL.)

M.K.S. System. The system of electrical and magnetic units founded on the metre, kilogram and the second, originally suggested by Professor Giorgi.

ml. Abbreviation for *millilitre*.

mm. Abbreviation for *millimetre*.

M.M.A.B. Minerals and Metals Advisory Board of the National Research Council, U.S.A.

M.m.f. *Magneto-motive force*.

Mn. Chemical symbol for *manganese*.

MnO. Chemical formula for manganese monoxide.

MnO_2. Chemical formula for manganese dioxide.

Mo. Chemical symbol for *molybdenum*.

Modell Number. A value, obtained from the formula Bhn/E $\times$ 10^6 = Modell = measure of wear resistance, in which Bhn = the Brinell hardness and E = the elastic modulus, from which it is claimed the wear factor of metals can be determined. The elastic cushion provided by low modell materials helps to minimize wear only as long as the foreign particles do not exceed a critical size which is dependent upon the elastic give of metal surfaces, the load, and the minimum clearance between the surfaces. Materials of high modell behave like a spring, absorbing energy and preventing loads from building up to a high value. (O. 1.)

Modified Bauer Vogel. (See M.B.V. PROCESS.)

Modulation Welding. A method of welding, which, while possessing all the advantages of quick spot welding, obviates the frequent interruptions of current. The voltage is made to fluctuate constantly between a maximum and a minimum value. This condition is obtained by means of a modulator which is essentially a single-phase induction regulator with revolving rotor. It produces a modulated voltage across the electrode rollers, the frequency of modulation depending on the number of poles and the speed of revolution of the modulator. (E. 64.)

Modulus of Cubic Compressibility. (See VOLUMETRIC MODULUS OF ELASTICITY.)

Modulus of Elasticity. (See YOUNG'S MODULUS.)

Modulus of Resilience. The amount of energy absorbed when one cubic inch of material is stressed to its elastic limit.

The modulus of resilience is proportional to the area under the elastic portion of the stress-strain diagram. Materials having a high modulus of resilience are capable of withstanding high impact without damage. (A. 26.)

Modulus of Rigidity. In a torsion test, the ratio of the unit shear stress to the displacement caused by it per unit length in the elastic range.

Modulus of Rupture. The ultimate strength or the breaking load per unit area of a specimen tested in torsion or in bending (flexure). In tension, it is the tensile strength. (A. 27.)

Modulus of Strain Hardening. When the true stress (σ) is plotted against the true strain (δ) in tensile testing, the slope of the tangent to the curve in the plastic range is sometimes called the strain hardening modulus. A better expression would be: rate of strain hardening, defined as $d\sigma/d\delta$. (A. 27.)

Mogullizer. Equipment for sealing by vacuum impregnation small pores in ferrous castings. In use, the work is loaded into the sealing tank of the unit and is first held under a vacuum of 29½ in. for twenty minutes to remove all air and moisture from the inner walls. Next, an impregnating solution is introduced. Compressed air at 100 lb. per sq. in. pressure is then applied to the work for another twenty minutes so that the solution is forced into the pores in the castings. Castings sealed by this process are claimed to be capable of withstanding tests with fluids such as hot oil or paraffin, under pressures as high as 10,000 lb. per sq. in. (M. 47.)

Mohrs' Salt. Ferrous ammonium sulphate.

Mohs' Scale. A method, published in 1822 and still in use, for determining comparative *hardness*, by testing against ten standard minerals: (1) talc, (2) gypsum, (3) calcite, (4) fluorite, (5) apatite, (6) orthoclase, (7) quartz, (8) topaz, (9) corundum, (10) diamond. Thus, a mineral with hardness 5 will scratch or abrade fluorite, but will be scratched by orthoclase.

Moisture. Water which can be driven off by heating at 105° to 110° C. (A. 26.)

Moisture Content. In sand moulding, the amount of water which should be sufficient to ensure plasticity, thus ensuring accurate delineation of the mould.

Moisture, Workable. In sand moulding, that range of moisture content within which the sand fills, rams, draws, and dries to a satisfactory mould, and within which the sand does not dry out too fast to mould and patch.

Mol. (See MOLE.)

Mol Fraction. The proportion of the number of molecules that a constituent bears to the total number of molecules in the same phase. Where compositions are stated in weight per cent, the mol fractions are calculated by first dividing the weight per cent of each constituent by its molecular weight and then dividing each result so obtained by the sum of all the results.

Mole. (*Mol.*) Gram molecular or gram formula weight. The quantity of a substance in grams (gram moles) or pounds (*pound moles*) corresponding to the sum of the atomic weights of all the atoms appearing in the molecular formula.

Molecular Concentration. The concentration of a solution expressed in terms of gram-molecules or *moles* in a given volume.

Molecular Shock. A process of welding, in which the weld is made by the application of high frequency current which serves as a molecular hammer. A temperature not exceeding 370° C. is attained during the operation. (A. 23.)

Molecular Weight. (*M.wt.*) The weight of a molecule of a substance relative to the weight of a hydrogen atom. It is the sum of the atomic weights of the elements in the molecule.

Molecule. The smallest particle of a substance which can exist by itself and still possess the chemical characteristic of that substance.

Moll Checkers. Oval-shaped *checker bricks* used in *open hearth furnace* regenerators. (S. 137.)

Moll-Demag Open Hearth Furnace. A furnace in which the air and gas are mixed together before they enter the hearth, rather like the air-gas mixture in a Bunsen burner. The air regenerators are made very large and are placed at the outside ends of the furnace: air temperatures of 1400° C. have been measured. This results in an intensely hot flame, which accelerates the melting of the charge, and the formation of the slag layer. A slag pan is used instead of slag pockets. The furnace is claimed to be more economical in operation than the ordinary type of open hearth, and to require fewer repairs. (See also MOLL PORTS.) (S. 30.)

Moll Ports. Ports for *open hearth furnaces* designed to ensure a more perfect mixing of the gas and air at the point of entry into the furnace. The flues are so arranged that the gas current is directed downwards at a slope towards the surface of the bath, and the air rises vertically from below and meets the stream of gas at right

angles before it enters the furnace. The port conveying the current of mixed gas and air is continued in the same plane as the gas fire, so that the direction of the gas current remains unchanged after meeting the air. The air uptake is more than twice the width of the gas flue, so that at the point where gas and air meet the stream, the gas strikes the much broader air current at its centre and the gas thus becomes enveloped in air and mixing is effected in the short port leading into the furnace. (M. 151.)

Mollerizing. A process for the impregnation of steel with aluminium. The steel parts, previously thoroughly cleaned, are lowered into standard salt-bath furnaces containing principally pure barium chloride upon which is floated a bath of pure aluminium. After heating to the temperature of the salt (870° to 1095° C.), the metal parts are removed through the aluminium, which enters the pores of the steel and forms a hard iron-aluminium alloy; an exterior layer, having the corrosion-resistant properties of pure aluminium, is also deposited. (S. 121.)

Molochite. (*a*) Calcined china clay. (*b*) A synonym for *malachite*, a basic cupric carbonate mineral.

Molybdenite. Molybdenum sulphide (MoS_2) containing about 60% of *molybdenum*, and one of the chief sources of that metal.

Molybdenum. (*Mo.*) *Atomic weight* 95·95. *Specific gravity* 10·2. *Melting point* 2622° C. A silvery-white malleable metal. The two most important commercial sources of molybdenum are *molybdenite* (MoS_2) and *wulfenite* ($PbMoO_4$). The metal is not found in the free state. Molybdenum metal may be prepared in several ways: e.g. ammonium molybdate is decomposed at red heat in an atmosphere of hydrogen to molybdenum powder. The same treatment may be given to other salts or oxides of molybdenum. Ferro-molybdenum is produced in an electric furnace. Molybdenum is supplied in a number of commercial forms suitable for making additions to steels, the most generally employed in the United Kingdom being ferro-molybdenum, calcium-molybdate, and calcium silico-molybdate. Molybdenum can be formed by rolling, swaging, forging, drawing, bending, stamping, machining, brazing, and welding, and is therefore available in the form of wire, rod, sheet, plate, bar, and seamless tubing. The influence of molybdenum in steel is closely related to that of chromium and tungsten; it greatly increases hardenability, and in proportions up to 1%, is more effective than either chromium or tungsten. When added to low alloy steels it has a marked effect in reducing *temper-brittleness.* In solid solution, molybdenum increases strength and toughness and improves resistance to creep at high temperatures. Like other elements of the same group it raises the temperature at which grain growth takes place in austenite and diminishes the softening which takes place on tempering. For these reasons it is widely used in engineering steels, particularly in automobile and aircraft construction and for use in conditions where high strength is required at elevated temperatures. Molybdenum is a very important constituent in *nitriding steels* where, in addition to its effect of increasing hardenability and reducing susceptibility to temper-brittleness, it increases the toughness of the case without affecting the hardness. It is used in non-deforming tool steels and die blocks and in certain high-speed steels where it is claimed to give increased shock resistance for such purposes as saw blades, punches and dies. Molybdenum is added to austenitic corrosion-resisting steels of the 18% chromium, 8% nickel type, where it increases the resistance to acetic acid and to certain concentrations of sulphuric acid. It is an essential constituent in many special heat-resistant steels recently developed for turbo-super chargers and gas turbines which demand high strength at very high temperatures. In addition to its use in the steel industry, it is employed for electrical contacts, supporting filaments in incandescent lamps and radio tubes. Molybdenum rod finds application where glass-to-metal seals are needed and is also made into resistance-welding electrodes and heavy-duty contact breakers. Commercially produced alloys include those with tungsten and with nickel, as well as powder metallurgy compositions containing silver, copper or graphite.

Molybdenum Disulphide. A mineral resembling graphite, both in appearance and to the touch. When highly refined and purified it has unusual qualities as a dry lubricant and may be applied in powder form to metal surfaces or used with carriers such as oil, grease and silicones. It has been incorporated in plastics and powdered metal compacts. It is effective at temperatures up to about 315° C. and under high pressure.

Molybdenum Oxide. A commercial compound of molybdenum (MoO_3) which is used as a finishing agent in making molybdenum steels.

Molybdenum Steel. (See MOLYBDENUM.)

Molybdite. A pale-yellow mineral consisting of hydrous ferric molybdate.

Moly-Black. An electroplating process which is claimed to produce lustrous, deep-black electrodeposits that have no colour refraction under an intense beam of light in a dark room. A mixture of molybdenum and nickel plating salts is used and the process is operated at low current densities. (S. 113.)

Molyte. Commercial *calcium molybdate*.

Monazite. A mineral containing about 0·02% of *europium*, and consisting essentially of phosphates of the rare earth elements and, therefore, a source of *neodynium*, *cerium*, and *thorium*. It is, in fact, the principal source of thorium, from which is produced the fissile element *uranium* 233. Extensive deposits of monazite have been found in several African Colonies. (E. 34.)

Mond Gas. The gas produced by passing air and a large excess of steam over coal-slack at about 650° C.

Mond Nickel Continuous Casting Process. A method of producing a continuous metal ingot or the like by pouring the molten metal into the top of an open-ended mould which is split longitudinally into sections which rapidly oscillate transversely with a small amplitude of movement, characterized in that the amplitude of the movement decreases towards the bottom of the mould. (M. 152.)

Mond Process. A method for the production of nickel. The raw material is ground nickel sulphide ore which is first roasted to eliminate the sulphur and convert the nickel to oxide. The oxide is then reduced to metal by water gas at a temperature of approximately 350°. The metallics then pass through volatilizers and at a temperature of approximately 50° C. the nickel is converted to a gas, *nickel carbonyl*, by reaction with carbon monoxide. The nickel carbonyl is then passed into decomposers where it is brought into contact with a stream of heated nickel pellets; the nickel carbonyl splits up, releasing carbon monoxide, and depositing the nickel on to the nickel pellets. These pellets are the final product and contain over 99·9% nickel.

Mond Weld Cracking Test. In this test, which is of the tied butt weld type, the test plates are mounted in a calibrated jig which restrains their movements due to welding stresses in two directions and which, by its own deflection, provides a measure of the forces exerted on it by the welded test plates. (L. 17.)

Monell Process. A steelmaking process, invented about 1900, in which, for example, 5 tons of limestone, followed by about 4 tons of iron ore, were charged into a basic-lined furnace, and heated to a state of semi-fusion. At this stage, about 30 tons of molten high silicon iron were added. Reaction quickly followed with the formation of a thick foaming slag which was removed after about 2 hours. In this way, most of the silicon and manganese, together with most of the phosphorus and some of the carbon, were removed. Fresh additions of iron ore and lime were then made and the charge worked down in the usual way. The method was not a practical success and was discontinued. The *Trade Heat Method* was a modification of the Monell process, in which the proportion of liquid metal in the charge was much less than that in the original.

Monkey. (See CINDER NOTCH.)

Mono-Cast Method. (*Sand-Spun.*) A method of producing centrifugally-cast pipes in sand-lined moulds. (M. 11.)

Monochromatic. Light or X-rays, having a single wave-length.

Monochromator. (See UNICAM S.P.600 SPECTROPHOTOMETER.)

Monoclinic. Crystals having only parallel 2-fold axes of symmetry, or parallel planes of symmetry, or both of these with the axes perpendicular to the planes. The typical monoclinic crystal has three unequal axes, only one of which is perpendicular to two others. The unique axis is usually taken as the b-axis. (A. 27.)

Monolithic Refractory. Furnace lining made in one piece or formed by casting, ramming or tamping into position.

Monomorphous. Existing in only one crystalline form.

Monotectic. An isothermal reversible reaction in a binary system where a liquid, during cooling, forms a solid and a second liquid of different composition. (A. 27.)

Monotron. An instrument for measuring indentation hardness. It is fitted with two dials, one registering the depth of penetration, the other measuring the load.

Monotropic. Existing in only one stable physical form, any other form obtainable being unstable under all conditions.

Monovalent. Univalent. Having a *valency* of one.

Montmorillonite. A very plastic clay, more siliceous than kaolinite. It is the principal constituent of bentonite.

Monypenny, John Henry. (1885–1949.) An English metallurgist; the author of *Stainless Iron and Steel* and of many papers on stainless steel and its application.

Mood. A Sheffield dialect variant of *mould*. The term is now applied in the cutlery trade to the first rough shape produced in the forging of a knife blade.

Mooding. The operation of forging the first rough shape of a knife blade.

Moore, R.R. Fatigue Machine. A constant load rotating bending type of machine in which the load may be as high as 10,000 in. lb. and the speed up to 3600 r.p.m. (A. 33.)

Moore Krouse Fatigue Testing Machine. This machine applies pulsating (zero-maximum) tensile stress by means of a lever driven by a variable throw cam. A steady compressive load is superimposed on the pulsating load by means of a helical spring, thus making possible any ratio between -1 to $+1$ of maximum to minimum load during a cycle of stress. The load, and consequently the stress, is measured by the deflection of an elastic ring to which the specimen is attached. (A. 35.)

Moore-Schafer Fatigue Machine. A vibratory flexural machine in which the specimen is vibrated as a cantilever beam by means of a variable throw crank and a connecting rod. The deflection of the specimen is measured by a micrometer dial gauge as the machine is turned over by hand, and each specimen before it is tested is calibrated as its own dynamometer by noting the deflection of the specimen under dead weights. (A. 35.)

Mop. (*a*) (See CRUCIBLE PROCESS). (*b*) A polishing wheel composed of layers of fabric held together by a central boss, rigidity being produced by centrifugal force. Additional rigidity may be conferred by stitching.

Morgoil Bearings. A type of oil-fed bearing to be found in rolling mills where there is little or no shock transmitted on to the roll necks. The oil is pressure fed to the roll neck and the bearing so that there is no metal to metal contact, i.e. the necks are separated from the bearings by a film of oil.

Morehouse Proving Ring. An elastic steel ring, designed primarily for measuring static loads by micrometer measurement of the ring's deflection, which is modified by replacing the vibrating reed with a spring-loaded plunger having double electrical contacts for indicating purposes. This permits measuring both maximum and minimum loads in tension and compression. (T. 25.)

Morocco Leather Skin. (See CROCODILE SKIN.)

M.O.S. Ministry of Supply.

Mosaic Structure. A structure of units, intermediate between unit cell size and grain size, which is presumed to exist in metals and alloys. Unit blocks are believed to be about 10^{-4} to 10^{-5} cm. along an edge. (A. 27.)

Moseley, Henry Gwyn Jeffreys. (1887–1915.) An English physicist who investigated the X-ray spectra of various elements.

Moseley's Law. The frequencies of the characteristic X-rays of the elements show a strict linear relationship with the square of the atomic number. This result of Moseley's researches stressed the importance of atomic number, and not atomic weight, in considering regularities in atomic structure.

M.O.T. Ministry of Transport.

Mother Liquor. The concentrated solution from which, on cooling, crystals are formed.

Mother Metal. The molten alloy just before final solidification and freezing out of the solid.

Mottle. Dull areas on tinplates.

Mottled Iron. Medium silicon pig irons in which about half the total carbon is in the form of graphite, and the remainder in the combined form. Graphitization commences from a series of centres and the graphite then exists in star-shaped masses which give rise to the characteristic mottled fractures. This material is hard, brittle and practically unmachinable.

Mottled Plate. (See MOTTLE.)

Mould (*a*) In the foundry, the cavity of desired shape, usually of sand, into which the molten metal is poured. (*b*) (See INGOT MOULD). (*c*) (*Moulder*). The product of the first stage of *cogging* down when the slab or sheet bar is cut into pieces suitable for the production of one or more sheets. These pieces are then reheated before submitting to further rolling.

Mould Board. The board upon which the pattern is placed in making the *mould*.

Mould Cavity. The impression left in the sand by a pattern.

Mould Clamps. Devices used to hold or lock together the *cope* and *drag* of the mould.

Mould Coating. (*Mould Dressing*.) A coating used to prevent surface defects on ingots. Various materials have been tried, powdered pitch, etc., but tar is usually considered most suitable. (See also DARMOLD and HYDROPASTE.) (W. 3.)

Mould Dressing. (See MOULD COATING.)

Mould Facing. Any substance applied to the face of the mould to give an improved casting finish.

Mould Jacket. A wooden or metal form which is slipped over a mould made in a snap or slip flask, to support the four

sides of the mould during pouring, maintaining alignment of cope and drag halves of mould. After pouring, jackets and mould weights are shifted to another row of moulds. (A. 26.)

Mould Shift. A casting defect which results when a casting does not match at parting lines. (A. 26.)

Mould Wash. Usually an aqueous emulsion containing various compounds, such as graphite, and silica flour. It is used to coat the face of the cavity in the casting mould. (A. 26.)

Mould Weights. Weights placed on the top of moulds to offset internal or ferrostatic pressure during pouring. (A. 26.)

Moulded Sections. (See ROLL FORMING.)

Moulder. (*a*) The craftsman who prepares the mould for the reception of the hot metal in the production of a casting. (*b*) (See MOULD).

Moulder's Rule. A rule used in making *patterns*, on which the graduations are expanded to account for thermal and solidification contraction of the metal being cast. (See PATTERNMAKER'S SHRINKAGE.) (A. 26.)

Moulding. As applied in a *foundry*, the term refers to the art of forming cavities (moulds) of a desired shape, i.e. that of the required *casting*, in a suitable refractory substance, usually moulding sand. Moulding is usually carried out by ramming sand round a *pattern*, which is then removed, and the cavity so formed is filled with molten metal, which on solidification retains the shape of the pattern used.

Moulding Board. The board on which patterns are laid whilst the drag is being made.

Moulding Box. (*a*) (See FLASK). (*b*) As applied to tubes, the term indicates a container, usually of metal, placed round a joint into which molten bitumen is poured and allowed to set. This ensures continuity of the protection of sheathed or otherwise protected pipes.

Moulding Gravel. The coarser and more permeable grades of *moulding sand*, generally used in the production of castings of exceptionally large size and weight. (A. 26.)

Moulding Hole. The pit in the floor of the foundry in which large castings are made.

Moulding Loam. (See LOAM.)

Moulding Sands. Sands used in the foundry for making *moulds* are divided into two classes: (*a*) *Facing Sand*, a specially prepared mixture used to form the face of the mould, where it will be in direct contact with the cast metal. (*b*) *Backing Sand*, which fills up the body of the *moulding box* or *flask* and supports the facing sand. The backing sand consists of *floor* or *black sand*, i.e. sand that has been in previous use.

Mountain Cork. *Asbestos.*

Mountain Flour. (See INFUSORIAL EARTH.)

Mountain Meal. (See INFUSORIAL EARTH.)

Moving Die Side. In pressure die casting, the half of the die which moves away from the fixed platen to allow of the removal of the casting.

m.p. *Melting point.*

M.P.A. Metal Powder Association. (U.S.A.)

M_s Point. (See TRANSFORMATION TEMPERATURE.)

M.T.I. Metal Treating Institute. (U.S.A.)

M.T.M. An abbreviation for *Methods Time Measurement.*

Muck Bar. Bar rolled from a squeezed bloom. (A. 28.)

Muffle Furnace. A furnace in which the heating is indirect and the charge is contained in a refractory container or crucible heated from the outside. The products of combustion are not in direct contact with the charge.

Mullard Ultrasonic Vibratory Drills. Ultrasonic vibrations of the order of 26,000 vibrations per second are used for the drilling and cutting of brittle materials, and primarily of glass, tungsten carbide, porcelain, quartz and tool steels. The instrument which is employed is essentially a high-speed reciprocating drill.

Muller. A type of foundry sand-mixing machine. (A. 26.)

Mulling. The process of mixing sand and clay particles by compressing with a heavy roller in preparation for moulding, i.e. it involves a process of mixing combined with a rubbing action as well as stirring.

Mulling Ratio. The ratio of water by weight to clay content by weight, used in the milling of moulding sand.

Mullite. A silicate of aluminium ($3Al_2O_3$, $2SiO_2$), very similar to *sillimanite*. It is formed at high temperatures from aluminous clay mixtures.

Multi-Layer Welding Process. (See BABCOCK MULTI-LAYER WELDING PROCESS.)

Multi Method. A method of magnetic analysis for the testing of tubes in which the magnetic properties of a tube, as it passes through a test coil at a speed of 30 ft./minute, are compared with those of a length of tube of known properties in a second coil. (S. 93.)

Multipass Weld. (*Layer Weld.*) A weld made by depositing several layers of metal, each deposit being allowed to cool and all slag and irregularities removed before the next pass is made.

It is claimed that such welds are characterized by their toughness and ductility. Multipass welds are generally used where steel sections of considerable thickness are involved.

Multiphase Alloys. Alloys possessing heterogeneous structures.

Multiple Arc Welding. The method, which permits the independent regulation of the heat input to the electrodes and work, requires three electrodes, two carbon, and one metallic. The two carbon electrodes, one of them earthed, are fed from a single welding transformer through a choke and resistance, and are fixed in a holder at an angle of about 30° to each other. The metallic electrode, fed from a special welding transformer through a rheostat, is held in an ordinary holder. Five arcs are formed.

Multiple Arc Welding Unit. Equipment designed for supplying current to two or more welding arcs in parallel.

Multiple Bar Weight. The *cut weight*, plus the loss in cutting.

Multiple-Beam Interferometry. The application of multiple-beam interference of light to the study of the surface topography of solids and the examination of the properties of thin films. Variations of surface height of but a few ångström units can be measured. Some crystal lattice spacings have, in fact, been evaluated with visible light waves. The various techniques have wide applications in chemistry, crystallography, crystal physics, and metallurgy. (T. 36.)

Multiple Drilling Machine. A drilling machine fitted with more than one spindle which can thus be used for simultaneous operation.

Multiple Flame Pressure Welding Process. This process consists essentially of heating the weld zone of pieces to be joined, by multiple oxy-acetylene flames, and applying pressure, normal to the weld faces, to force the pieces to bond together. (C. 60.)

Multiple-Impulse Weld Timer. In *resistance welding*, a device for multiple-impulse welding which controls only the heat time, the cool time, and either the weld interval or the number of heat times.

Multiple Impulse Welding. (See PULSATION WELDING.)

Multiple Lengths. Lengths of bar or wire which can be cut up into shorter pieces of specified length without waste.

Multiple Mould. A composite mould made up of stacked sections, each of which produces a complete *gate* of castings and is poured from a central *downgate*. (A. 26.)

Multiple Projection Welding. A resistance welding process in which two or more welds are made simultaneously and in parallel.

Multiple Proportions Law. This states that when two chemical elements combine to form more than one compound, the weights of one of them which combine with a fixed weight of the other are in the proportion of small whole numbers and thus exhibit a simple multiple relation.

Multiple Spot Weld. A group of spot welds made simultaneously by the aid of two or more pairs of contact points, which are connected in parallel with the operating transformer or transformers. The welds may be arranged in chain form or staggered. (B. 105.)

Multi-Ply Metal Stock. Metal stock formed by applying pressure at temperatures from 870° to 1010° C. for a period of about 2 hours, to layers of metal which have bonding affinities e.g. austenitic stainless steel and copper. (K. 22.)

Munsell Colour System. A system of specifying hue, strength and other colour characteristics by symbols and figures. Through the use of the system, colours, neutral shades and any variations from either can be described. (R. 14.)

Muntz Metal. (See BETA BRASS.)

Murakami's Reagent. An etching reagent developed for use in the investigation of the structure of iron-carbon-chromium alloys. It consists of a solution of:

10 grams potassium ferricyanide,
10 grams potassium hydroxide,
100 ml. water.

(M. 177b.)

Murex Hot-Cracking Test. A test for welding quality in which a weld is made between two plates which are set up in a machine to form a joint for a gravity position fillet-weld. One of the plates is fixed rigidly in the machine, while the other can be rotated about an axis which runs through the root of the weld, so, in effect, opening out the legs of the fillet. The legs of the fillet are opened out while the weld is being made, and the conditions of the deformation which are imposed upon the solidifying and cooling weld-metal are such that hot-cracking will occur in steels that are susceptible to it. The amounts of cracking which actually occur are indications of the relative susceptibilities of different materials to hot-cracking during welding. The machine is so constructed that the legs of the fillet can be opened at various speeds; this permits of a greater discrimination

being made between the cracking tendencies of different steels than is possible with the *T cracking test*. (M. 177a.)

Muriatic Acid. *Hydrochloric acid.*

Muschenbroek Hardness Test. A hardness test devised in the early part of the eighteenth century. It employed an edged tool set in the end of a pendulum which was allowed to fall from a specified distance against the specimen, the hardness being calculated from the number of blows required to cut the test piece into two, divided by the density of the said test piece.

Muscovite. Common *mica*, potassium aluminium silicate.

Mushet, David. (1772–1847.) A Scotsman and the discoverer of *Blackband Ironstone*. He was the father of *Robert Forester Mushet*.

Mushet, Robert Forester. (1811–91.) A Scotsman who perfected the Bessemer process by the addition of *spiegeleisen* to the blown metal, and invented *Mushet steel*, which he began to manufacture in Sheffield in 1870.

Mushet Steel. An *air-hardening* or *self-hard* steel, containing about 2% carbon, 2% manganese, and 7% tungsten.

Mushroom Core Print. This type of print is larger than the core which, as the name implies, it overhangs.

Mushy Stage. The state between solid and liquid in alloys which freeze over a range of temperature.

Music Wire. (See PIANO WIRE.)

Musso Process. A mixture of iron ore and fuel is reduced in an externally heated rotary retort. The gases are exhausted and constitute the fuel when the process has been started. The gases, after purification, are passed through combustion rings surrounding the retort and are burned according to the method of catalytic combustion. After reduction, the charge is cooled, when it is poured through a layer of fluxing material, it is then transferred to a steel-making furnace. (I. 43.)

Mutual Indentation Method of Hardness Testing. A method of hardness measurement in which crossed prisms or cylinders of the material under test are forced together. It is claimed that the results are comparable with those obtained by the *Brinell test*. (C. 55.)

M.wt. *Molecular Weight.*

N

N. (*a*) Chemical symbol for *nitrogen*. (*b*) Abbreviation for *normal solution*. (*c*) Abbreviation for *normalized*.

Na. Chemical symbol for sodium, from the Latin *natrium*.

N.A.C.A. (See NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.)

N.A.C.E. National Association of Corrosion Engineers (U.S.A.).

N.A.C.M. National Association of Colliery Managers.

Naeser Colour Pyrometer. An optical instrument in which temperature measurement depends upon the variation in colour. (V. 10.)

Nagaska-Honda Effect. (See MAGNETOSTRICTION.)

Nailing. (See CRUCIBLE.)

Nailing In. Assembling and riveting pocket knives.

Naismith Back Wall. A sloping back wall which follows the general lines of a tilting furnace wall, although the slope is somewhat accentuated. It has been used for fixed open hearth furnaces with the result that the repair of the back wall is appreciably facilitated. (W. 67.)

N.A.M.E. National Association of Marine Engine Builders.

Nascent. Actually, "newly born", i.e. an element just released by chemical reaction and therefore very reactive. It is believed that this activity is due to the fact that the elements at the moment of release are in the atomic state.

Nasmyth, James. (1808–90.) A Scots engineer who, in 1842, patented the steam hammer by which his name is best known.

Nathusius Furnace. An early type of combined arc resistance furnace in which three vertical carbon electrodes passing through the roof were arranged at the apices of an equilateral triangle and connected to the outer ends of a secondary circuit of a three-phase generator, whilst three steel electrodes built into the bottom of the furnace, also in a triangle, were connected to the inner ends of the secondary circuit of the same generator so that the neutral point of the machine was transferred into the charge itself. (B. 23.)

National Advisory Committee for Aeronautics. (U.S.A.) A number of the documents issued by the *N.A.C.A.* are available on loan at the Technical Information Bureau, Reference Library, Ministry of Supply, First Avenue House, High Holborn, London, W.C.1.

National Armament Works Hardness Tester. A direct-reading machine in which the degree of hardness is given by penetration of two opposed points between which the test piece is gripped. The reading gives the sum of depth of two penetrations opposite to one another, and measures the mean hard-

ness of the opposite faces. The values obtained are calibrated to Brinell numbers. (E. 20.)

National Bureau of Standards. (See BUREAU OF STANDARDS.)

National Bureau of Standards High-H Permeameter. An instrument which has been designed for magnetic testing in the range of values from 100 to 5000 oersted. Specimens of permanent magnet alloys with a cross-section up to 1½ × ¾ in. can be tested with it, and it is estimated that under ordinary conditions of routine testing the readings are accurate to within 1%. (S. 9.)

National Bureau of Standards Hot Hardness Tester. An instrument employing very low loads for measuring the hot hardness of electrodeposits. To eliminate oxide films, specimens are heated and tested in an inert gas atmosphere. The apparatus consists essentially of a Vickers diamond indenter mounted on a vertical shaft of fused silica, a mechanical device for raising and lowering the indenter, an electric furnace for heating the specimens, and a micrometer device for orientating the specimens. (I. 37.)

National Coating. A reinforced rubber compound coating applied to iron and steel piping intended for service in underground conditions.

National Emergency Steels (U.S.A.). (*N.E. Steels.*) A series of steels evolved in 1942, in the U.S.A., under the leadership of the American Iron and Steel Institute.

National Physical Laboratory. Teddington. (*N.P.L.*) This laboratory comprises ten scientific Divisions, each under a Superintendent. These are as follows: Aerodynamics; Electricity; Engineering; Light (Optics and Photometry); Mathematics; Metallurgy; Metrology (including Control Mechanisms); Physics (Heat, Sound Radiology); Radio; Ship. The purposes of the National Physical Laboratory include the determination of physical constants, the maintenance of precise standards of measurement, and to test instruments and materials. It carries out special investigations on behalf of Government Departments, research organizations, and industrial firms, fees being charged for work done for non-Government bodies.

National Physical Laboratory Testing Machine for Combined Tension and Torsion. A machine constructed for the purpose of studying plastic flow at high temperatures under time independent conditions. It can be used for carrying out tests on specimens under tension, torsion, tension with any fixed static torsion, torsion with any fixed static tension, or with the ratio of tensile load to twisting moment remaining constant throughout the test at any desired value from 0·2 to 10. (P. 30.)

National Research Development Corporation, 1 Tilney Street, London, W.1.

Native. A term applied to metals occurring in the uncombined or metallic state, and not as an oxide or sulphide, e.g. *gold.*

Natrium. The Latin name for *sodium.*

Natrometer. An instrument for estimating the quantity of sodium contained in mixtures of sodium and potassium salts.

Natural Ageing. (See AGEING.)

Natural Sand. Sand derived from a rock, in which the grains separate along their natural boundaries. This includes unconsolidated sand, or a soft sandstone where little pressure is required to separate the individual grains. (A. 26.)

Naturally Bonded Moulding Sand. This term as used by foundrymen refers to a sand which as mined contains sufficient bonding material for moulding purposes. (A. 26.)

Nature. A term formerly used to describe the characteristics of steel, e.g. burnt steel was said to have no "nature". (Cf. PUDDLING.) (See also COMING TO NATURE.)

Nature Prints. *Macrographs* obtained by deeply etching a steel surface with an acid reagent which shows up the structure in relief. The surface is inked and printed on to paper.

Naval Brass. Brass containing a small percentage of tin. Typical composition, copper 60%, zinc 39%, tin 1%, the addition of tin imparting additional strength and resistance to corrosion by sea-water.

Navy Tear Test. (**U.S.A.**) A method of evaluating the susceptibility of ship plate to brittle or cleavage type fracture, which uses a notched test specimen 3 × 5 in. × full plate thickness which is symmetrically loaded in static tension to complete failure under controlled temperature conditions. The load extension diagram obtained for each specimen indicates the energy input required to (i) start initial failure and (ii) propagate the fracture to completion. (K. 2.)

Navy Wear Testing Machine. (U.S.A.) The machine, which is characterized by its strength and rigidity, has two sliders, reciprocating in opposite directions, each with a capacity of twelve test pieces. Driven by a 15 h.p. electric motor at a speed of about 1500 r.p.m., it reproduces the pressure, reciprocating contacts, rubbing velocities and piston

stroke reversals, prevailing at the top of the stroke of a Diesel engine cylinder. A lubricating system sprays a fine film of artificially contaminated oil. A thermocouple is attached near the bearing surface of each piston ring. After the test the amount of chromium plate wear is determined. The wear test is followed by micrographic and X-ray analyses. (G. 66.)

Nb. Chemical symbol for *niobium*.

N.B.F.U. National Board of Fire Underwriters.

N.B.S. National Bureau of Standards (U.S.A.).

N.C.B. National Coal Board.

Nd. Chemical symbol for *neodymium*.

NDHA Corrosion Tester. The instrument consists of three helical wire coils supported by a frame and electrically insulated from each other and the frame. The coils are the specimens the weight losses of which are determined. (C. 44.)

Ne. Chemical symbol for *neon*.

N.E. Steels. (See NATIONAL EMERGENCY STEELS (U.S.A.).)

Neck. (*a*) (See ROLLING MILLS). (*b*) A connection in the bustle pipe of a blast furnace through which the hot blast passes to the *goose neck*.

Necking. The reduction in cross-sectional area which occurs, to some degree, prior to fracture in most *tensile* test pieces. It is a characteristic of ductile materials, the higher the ductility of the material under test, the greater the necking. Fracture normally occurs in this region. (See also ELONGATION.)

Neck Down. An American term for a *Washburn core*.

Necking Down. The narrowing of the diameter of a wire at the point at which a break is about to occur.

Needle Ironstone. (*Gothite*.) An iron ore consisting of a hydrated oxide of iron ($Fe_2O_3.H_2O$) found, as the name implies, in acicular crystals.

Needle Thermocouples. These consist of an insulated wire representing one component, which is inserted into a tube, representing the second component, the hot junction between rod and tube being formed by welding. They can be made quite small in diameter by using hypodermic needle tubing and fine wire inserts, the insulation being held in place by the tube itself and the tube serving as its own protection. Because of their flexibility and small size, these couples can be threaded through small and winding passageways. (R. 3a.)

Needled Steel. A steel to which a *needling agent* has been added.

Needlers. (See NEEDLING AGENTS.)

Needles. (*a*) Elongated crystals, tapering at each end to a fine point, as those typical of *martensite*. (*b*) Metal powder particles of elongated form, resembling needles.

Needling Agents. Special addition agents containing boron which are claimed to have the property of markedly increasing the hardenability of the finished steel.

Negative Creep. A term used to indicate contraction in tensile creep testing.

Negative Hardening. (See NEGATIVE QUENCHING.)

Negative Ion. (See ANION.)

Negative Quenching. (*Negative Hardening*.) Accelerated cooling, e.g. in water or oil, from a temperature below the *critical range*. There is therefore, no transformation to suppress and the structure so treated remains unchanged.

Negative Segregation. (See INVERSE SEGREGATION.)

Neilson, James Beaumont. (1792–1865.) The inventor of the hot blast (instead of cold) for blowing blast and other furnaces.

Nelson Stud-Welding Pistol. An instrument for the semi-automatic welding of steel studs on to plates. The process is carried out as follows: the stud is loaded into the chuck forming the barrel of the pistol, a ferrule containing a flux is placed on the end of the stud, and this is then held against the plate. The trigger is pressed to switch on the current and a solenoid coil lifts the stud, creates an arc, and forms a pool of metal on the plate and the end of the stud. When the pre-set arcing period is completed the welding current and the solenoid are cut out, and the main spring of the pistol pushes the stud against the plate. (S. 73.)

N.E.M.A. National Electrical Manufacturers Association. (U.S.A.)

Neodymium. (*Nd.*) A yellowish metal belonging to the rare earths, found in *cerite*, *monazite* and *orthite*. *Atomic weight* 144·27. *Specific gravity* 7·05. *Melting point* 840° C.

Neon. (*Ne.*) Colourless, odourless, invisible gas belonging to the inert gases. *Atomic weight* 20·183. It occurs in minute quantities in the atmosphere. A discharge of electricity through neon at low pressures produces an intense orange-red glow. It is used for neon signs, and in glow discharge lamps.

N.E.P.A. Project. Nuclear Energy for the Propulsion of Aircraft Project.

Nephelometry. In nephelometry, dispersed particles actually scatter the incident light, which is measured at right angles and related to the concentration of the particles.

Neptunium. (*Np.*) A fissionable material. *Atomic number* 93. *Atomic weight* 237. (See PLUTONIUM.)

Nernst Effect. The potential difference between two edges of a metallic strip, in which heat flows longitudinally, when the strip is placed perpendicularly across a field of magnetic force.

Nernst Theory. An explanation of the development of electrode potentials, based on the supposition that an equilibrium is established between the tendency of the electrode material to pass into solution and that of the ions to be deposited on the electrode.

Nertalic-Aircomatic Welding. An arc welding process, carried out in an argon atmosphere, in which the weld metal is transferred by pulverization.

Nervous Welding. Low voltage, high amperage welding in combination with compressed air and a vibrator. It is used for repairing iron and steel castings and is applied with a pistol equipped with a trigger for manual feeding of the welding rod. The *electrode* is heated to the plastic stage and broken down by air. The recoil of the vibrator forges the hot metal into the defect under repair. (K. 55.)

Nesh. A term applied to material which is weak and easily ruptures under hot working operations. Synonymous with *hot short*.

Nessler Tubes. Matched glass cylinders with strain free, clear glass bottoms for comparing colour density; used in colorimetric analysis.

Nesslerization. A colorimetric process for the determination of ammonia by its reaction with *Nessler's reagent*.

Nessler's Reagent. A strongly alkaline solution of potassium mercuric iodide. It is used as a test for minute quantities of ammonia, which impart to it, a yellow colour.

Net Ton. *Short ton* (2000 lb.).

Network Structure. A structure in which the grains or crystals of one constituent are partly or entirely enveloped in another constituent. An etched section through the crystals resembles a network. For example, in certain conditions *hypo-eutectoid* steels show a network of *ferrite* on a background of *pearlite*, whilst in *hyper-eutectoid* steels the network is of *cementite* on a background of *pearlite*.

Neumann Bands. Narrow bands differently oriented within a grain of *ferrite*. Ordinarily these bands are formed only on deformation by impact, but in some alloys (silicon ferrite, for example), and particularly at low temperatures, the bands are formed more readily, as in ordinary cold working processes. It is suggested that the Neumann band is primarily a shearing or faulting movement operating along the pre-existent planar disjunctions of the mosaic structure, and as a secondary operation, twinning may be completed, as is known to be possible in ferrite.

Neutral. Neither acidic nor basic; if referring to an aqueous solution, having a pH value of 7, i.e. that of pure water.

Neutral Atmosphere. An atmosphere which is neither oxidizing, reducing, nor carburizing, i.e. in which neither hydrogen nor oxygen is in excess. The term is generally used in connection with furnace conditions.

Neutral Flame. A term used in *gas welding* to describe a flame in which the supplies of oxygen and fuel gas are so balanced that complete combustion of the fuel gas is obtained, the flame being neither oxidizing nor reducing. In the case of *oxygen* and *acetylene*, the gases are usually in approximately equal proportions. The neutral flame is indicated by the fact that the white inner cone is sharply defined and as large as possible.

Neutral Linings. Furnace linings of *neutral refractories*.

Neutral Point. (*a*) In chemical analysis, that point at which acidity and alkalinity are completely balanced. (*b*) In rolling, that point at which the rate of flow of the metal being rolled is equal to the peripheral speed of the rolls.

Neutral Refractory. A refractory material which is neither definitely acid nor definitely basic. The term is merely relative in most cases, since at high temperatures such a material will usually function as a weak acid, reacting with a strong base, or as a weak base, reacting with a strong acid. Chrome refractories are the most nearly neutral of all commonly used refractories. (A. 26.)

Neutral Steel. The name applied to steel produced from acid quality raw materials in a basic lined furnace, using a slag which contains sufficient lime and silica to prevent it reacting either as an acid or basic slag.

Neutralization. The chemical reaction between an acid and a base in such precise proportions that the characteristics of each disappear. The solution so produced contains a salt.

Neutron. Particle of the same mass as a *proton* but having no electric charge. (See ATOM.)

Nevill Continuous Casting Apparatus. Apparatus for the continuous casting of metal bar, slab, or like stock comprising an annular trough mounted for rotation about its centre of curvature

and having a cross-section conforming to the desired cross-sectional shape of the stock to be cast, means for feeding molten metal into the trough at a pouring point, means for removing the solidified stock at a stripping point, and means for continuously rotating the trough in a desired plane during the pouring and stripping operations. (N. 9.)

Newkirk Furnace. This furnace utilizes a three-phase power supply. It has a hearth electrode, very similar to that in the *Greaves-Etchells furnace*, connected with the neutral point of the transformer, and three graphite electrodes, entering by the roof, and arranged in line from the back of the furnace towards the pouring spout. The graphite electrodes are connected up with the three secondary transformer phases in star. Provided that the phase loads are balanced, no current passes through the hearth, and the furnace works like the *Fiat furnace*. During the melting period, load fluctuations occur, and the hearth resistance tends to neutralize these. If, during the refining period, it is considered desirable to heat the hearth from below, this can be done by changing the amount of current flowing through any one of the upper electrodes, thereby unbalancing the loads, and causing an appreciable return current to flow through the hearth. (I. 21.)

Newman Hardness Tester. A portable precision instrument of the *Rockwell* type, covering C, B and E scales; all other scales are covered by a transposing chart.

Newton, Sir Isaac. (1642–1727.) An English physicist and mathematician.

Newton's Law of Cooling. The rate at which a hot body cools is proportional to the difference in temperature between the body and its surroundings.

Ni. Chemical symbol for *nickel*.

Nib. In *powder metallurgy*, a pressed, presintered, shaped, sintered, hot pressed, rough drilled, or finished compact; also a generic term used for a piece of hard carbide material intended for use as a drawing die.

Nicarb Process. (See CARBO-NITRIDING.)

Nick-Break Test. A test for welds in which a welded specimen is nicked in the weld and bent until fracture occurs, the quality of the weld being judged by the behaviour of the specimen and the appearance of the fracture.

Nicked Bend Test. The test piece is lightly and evenly nicked on one side and the vee opened by bending the ends of the test piece back, either by means of a steadily applied pressure or by a succession of light blows. It is required that the open vee shall show fibre throughout and shall be free from dirt, localized concentrations of slag or coarse crystalline spots or streaks. (B. 100.)

Nicked Tensile Test. A test for wrought iron chain which is fractured with as little deformation of the structure as possible, to permit examination for impurities. The sample, consisting of 5 links, is tested as follows: the central link is nicked at the centre on the face of one side and on the reverse face of the other side to a depth of one-quarter of the diameter and the sample is then strained to destruction in tension in order to produce fractures on both the notched sides of the central link. It is required that the fractures thus produced shall show a clean silky fibre throughout, free from dirt, localized concentrations of slag or any coarse crystalline spots or streaks. (B. 100.)

Nickel. (*Ni.*) *Atomic weight* 58·69. A silvery-white metal with a *specific gravity* "as cast" of about 8·69, and "as rolled" of about 8·87; *melting point* 1455° C. The chief sources of the metal are the Sudbury Mines in Canada, which provide about 85% of the world's supply, and New Caledonia in the Pacific. The principal nickel minerals in the Sudbury Mines are *pyrrhotite* and *pentlandite*, whilst the chief New Caledonian ore is *garnierite*. The metal is produced from the ore by the *Mond process*. The metal is sold in the form of electrolytic nickel containing 99·95% nickel (including up to about 0·3% cobalt); nickel shot containing about 99·65% nickel with cobalt as before and small amounts of impurities such as iron, silicon, and copper; "F" nickel with cobalt as before and 1·8% iron and 5·75% silicon; and nickel ingots containing 99·2% of nickel. Nickel is used extensively as an alloying element in both ferrous and non-ferrous alloys, for coinage, nickel plating and as a catalyst. *Nickel Steel.* The addition of nickel, in amounts up to 8% or 10%, to low carbon steel, increases the tensile strength, and considerably raises the impact resistance, but in regard to ductility, as represented by elongation and reduction of area, the effect is negligible and, if anything, unfavourable. In structural steels it is usually present in amounts up to 5%. High nickel increases resistance to corrosion, and in combination with chromium it is used in the austenitic corrosion resisting steels. Certain iron-nickel alloys have unique properties, alloys with about 36% nickel having very low coefficients of expansion, whilst with 78·5% nickel

an alloy is obtained having a very high magnetic permeability in low fields.

Nickel-Carbon Couples. (See THERMOCOUPLES.)

Nickel Carbonyl. ($Ni(CO)_4$.) A gas which decomposes when heated to 200° C. into pure nickel and carbon monoxide. (See MOND PROCESS.)

Nickel-Clad Steel. The process of cladding steel plate with a sheet of nickel. It consists of producing a sandwich of two steel plates with two nickel sheets in between, separated by a mixture of magnesium oxide and sodium silicate, followed by rolling. (S. 49.)

Nickel Prints. A method of taking permanent records of steel surfaces, for identification of certain characteristics. The steel surface is fumed for 5 to 10 minutes over nitric acid (specific gravity 1·4), and subsequently covered with a gelatine paper saturated with ammonium hydroxide. After 1 to 2 minutes, nickel in amounts of over 0·2%, can be detected by touching the paper with a drop of thio-oxalic acid diamide in alcohol. The amounts of copper usually present in steel do not interfere with the reaction. The method is useful in detecting segregation of nickel in steel. (T. 19.)

Nickel Silvers. A group of alloys of copper, nickel and zinc, in varying proportions. The quality is determined by the nickel content, the better qualities may contain as much as 30% and the inferior qualities as little as 7% nickel. *German Silver* contains 18% to 25% nickel, 20% to 30% zinc, and the remainder copper, the corrosion resistance increasing with the nickel content. A typical *Sheffield Nickel Silver* contains about 24% nickel, 19% zinc and the remainder copper. Some of the nickel silvers contain small amounts of cobalt, lead and iron.

Nickel Steel. (See NICKEL.)

Nickelferrite. (See FERROFERRITE.)

Nickelizing. Building up a surface with nickel by means of electrodeposition.

Nicker-Pecker. An old Sheffield name for a file cutter, i.e. of hand cut files.

Nicking. Making a groove in a bar in order to set off the amount required for the production of a single forging.

Niclad. Composite sheets made by rolling together sheets of nickel and mild steel, to obtain the corrosion resistance of nickel with the strength of steel. (See also NICKEL-CLAD STEEL.)

Nicol Analyser. (See NICOL PRISM.)

Nicol Prism. A device for obtaining plane-polarized light. It consists of a crystal of Iceland spar which has been cut and cemented together in such a way that the ordinary ray is totally reflected out at the side of the crystal, while the extraordinary plane-polarized ray is freely transmitted. Conversely, when the incident light is already plane-polarized, the device is known as a Nicol analyser.

Niessner Slag-Print Process. A printing method for revealing oxide and non-metallic inclusions in steels. Gelatin paper is soaked for a few minutes in 5% hydrochloric acid; the greater part of the liquid is then removed by careful blotting and the moist paper is laid for a few seconds on the steel surface to be examined. The paper is then laid in a solution of potassium ferrocyanide (20 g. per litre) to develop the print. Intense blue colouration appears where non-metallic inclusions containing iron have been in contact with the paper. (D. 29.)

Nigger Head. A term applied in American open hearth practice to lumps of raw material which remain solid after the remainder of the charge has been melted down.

NiO. Nickel oxide or nickelous oxide, i.e. the formula corresponding to the commonly understood use of the term nickel oxide.

NiO_2. Chemical formula for nickel dioxide or nickel peroxide.

Nil Ductility Transition Temperature. (See DROP WEIGHT TEST.)

Niobium. (*Nb.*) *Atomic weight* 92·91. *Specific gravity* 8·57. *Melting point* 2415° C. A grey lustrous metal. Formerly it was known alternatively as *columbium* (Cb) but the name niobium has now been adopted by international agreement. It is almost invariably found in association with *tantalum*, to which it is closely related. Nigeria has hitherto provided 95% of the world's requirements, the chief ore being *columbite*. Niobium metal can be produced by several methods, e.g. electrochemically, or by aluminothermic reduction of the ore, but for steel making purposes it is used in the form of ferro-niobium which is added to the molten steel bath; for the production of the ferro-alloy, Nigerian ores are concentrated and reduced by aluminothermic method. Niobium is a strong carbide forming element and as such is added to certain austenitic corrosion resistant steels of the 18/8 chromium nickel type for the prevention of *intercrystalline corrosion*. Where niobium is used as the stabilizer, it is usually specified that it should be present in an amount at least 8 times that of the carbon content, the theoretical ratios of niobium to carbon required to form a carbide being 7·74 to 1.

Further, niobium is often used as a constituent of the electrodes used in the welding of such steels. Heat resisting steels containing niobium have been developed to meet the demands of gas turbine rotors in which blade root temperatures of up to 700° C. are involved. Another development is the addition of niobium to chromium-aluminium nitriding steels to accelerate the rate of the nitriding process.

Nipper Process. A method of hot working cast iron in which the material is uniformly heated in an annealing furnace to a temperature of, for example, 950° to 1150° C. and then rolled in an ordinary rolling mill. (N. 15a.)

Nital. A solution of nitric acid in methyl or ethyl alcohol, 1·5% by volume, used as an *etching* agent in ferrous metallography. It may be used to reveal the depth of case in nitrided and case hardened steels and gives good contrast between ferrite and cementite in pearlite or between ferrite and austenite, martensite and troostite.

Niton. The original name for *radon.*

Nitralizing. A pre-enamelling treatment for steel sheets, in which the metal after degreasing and acid pickling is immersed in fused sodium nitrate at 500°. (G. 16.)

Nitralloy. (See NITRIDING.)

Nitrate. A salt of *nitric acid.*

Nitric Acid. (*Aqua Fortis.*) (HNO_3.) *Specific gravity* 1·50. In less concentrated form it is used for dissolving metals, and in dilute solutions as an etching reagent. It has an oxidizing or passivating effect on stainless steels.

Nitric Acid Test. (See HUEY TEST.)

Nitrides. Compounds of metal with *nitrogen.*

Nitriding. (*Nitrogen Case-Hardening.*) A process for producing a hard surface on special types of steel by heating in contact with partly dissociated ammonia or other suitable medium for a period of up to about 90 hours at a temperature of about 500° C. A surface of abnormal hardness can be obtained only on special types of steel. The original *Nitralloy* steels range between 0·2% and 0·5% carbon, with about 1·5% chromium, 1·10% aluminium and 0·20% molybdenum, but in recent years other grades have been developed which contain no aluminium and are characterized by possessing a *case* of lower intrinsic hardness and greater *ductility* and *toughness.* The various types of Nitralloy steel embrace a range of surface hardness from 600 to 1100 diamond number.

Nitrogen. (*N.*) *Atomic weight* 14·008. At ordinary temperatures it is an odourless and colourless gas. The atmosphere contains 79% nitrogen in the free state. It is non-poisonous and does not support combustion. Small quantities of nitrogen are used in incandescent lamps to prevent arcing. Fixation of nitrogen is a term applied to any process whereby nitrogen from the atmosphere is transferred into nitrogen compounds, such as ammonia. Nitrogen in the usual amounts found in low carbon steels gives rise to precipitation and age hardening effects unless neutralized by special additions. It can be combined with many metals to form nitrides and is thus applied to the hardening of steel, the usual source for this purpose being ammonia. It is claimed that the incorporation of nitrogen in austenitic chromium nickel steels increases the creep-resistance, and that nitrogen may be substituted for part of the nickel content of such steels and still preserve the face centred cubic lattice. It is also claimed that the addition of nitrogen to high chromium steel materially increases the strength and toughness and reduces grain growth during hot working, e.g. by inducing the formation of certain amounts of austenite. (See also NITRIDING.)

Nitrogen Case-Hardening. (See NITRIDING.)

Nitrogen in Steel. (See NITROGEN.)

Nitroneal Generator. An apparatus for producing protective gas atmospheres for the heat treatment of metals. It combines in one process the simultaneous cracking and burning of ammonia. The generator employs a platinum metal catalyst through which a controlled mixture of air and ammonia is passed. The catalyst ensures the complete conversion of all the oxygen to water vapour, which is then removed partly by condensation and partly by conventional dryers.

NO. Chemical formula for nitric oxide (nitrogen dioxide).

N_2O. Chemical formula for nitrous oxide (nitrogen monoxide).

N_2O_3. Chemical formula for nitrogen trioxide.

N_2O_4. Chemical formula for nitrogen peroxide (or tetroxide).

N_2O_5. Chemical formula for nitrogen pentoxide.

Nobbing. An alternative spelling of *knobbling* and synonymous with *shingling.*

Nobbling. An alternative spelling of *knobbling* and synonymous with *shingling.*

Noble Metal Thermocouple. (See PLATINUM-PLATINUM/RHODIUM THERMOCOUPLE.)

Noble Metals. Metals, e.g. gold and platinum, which do not tarnish or corrode in air or water and which are resistant to corrosion by all but the most powerful acids, such as *aqua regia*. It is owing to their characteristic corrosion-resistance that the noble metals occur *native*. (See ELECTRO-CHEMICAL SERIES.)

Noble Potential. A potential substantially cathodic to the standard hydrogen potential.

Noblins. Shingled blooms obtained in the production of wrought iron.

Nodular Graphite. The term has been employed for many years to describe the form of graphite found in *black heart malleable cast iron*. It is now sometimes used in reference to the newer *spheroidal graphite cast irons*, which is liable to lead to some confusion.

Nodular Graphite Cast Iron. *Spheroidal Graphite Cast Iron*. (See CAST IRON.)

Nodular Powder. In *powder metallurgy*, irregular particles that have knotted, rounded or other similar shapes. (A. 27.)

Nodulizing. A method of agglomerizing fine iron ore which is charged into the upper end of an inclined rotary kiln heated at the lower end to a temperature of about 1400° C., the ore, during its descent with rotary movement, balling up into nodules.

N.O.H.C. National Open Hearth Committee (U.S.A.).

Noise Thermometer. A *thermometer* for high temperatures and high pressures, with a null device for determining the ratio of two absolute temperatures with an accuracy of 0·1%. It balances mean-square fluctuations in voltage across the terminals of two resistors arising from thermal agitation at the temperatures to be compared. The ratio of resistance, when noise voltages from the two resistors are equal, determines the ratio of their absolute temperatures. (G. 5.)

N.O.L. Naval Ordnance Laboratory, White Oak, Md., U.S.A.

Nominal Bore. A term used to indicate the sizes of certain pipes. Such pipes are standardized as to outside diameter, and for any one nominal bore size the outside diameter is the same, but the thickness may vary according to the purpose for which the pipes are to be used, and the bore may differ correspondingly from the nominal bore.

Nominal Percentage Reduction of Area. The *nominal reduction in area* expressed as a percentage of the original cross-sectional area of the specimen. It is equal to the *nominal unit reduction in area* multiplied by one hundred.

Nominal Stress. (See TRUE TENSILE STRESS.)

Nominal Unit Reduction in Area. The ratio of the *nominal reduction in area* to the original, cross-sectional area of the test specimen, that is, the nominal reduction in area per unit original cross-sectional area. It is expressed as a dimensionless ratio.

Nomogram. A diagram by means of which the value can be rapidly determined of a quantity which is a function of one or more other quantities.

Nomy Pad Bearing. A type of frictional bearing in which the rotating bearing surface is divided into a number of small parts or pads, which are supported away from their middle points. In operation these pads automatically take up a position forming a small angle with the outer fixed bearing surface. The resulting wedge-shaped oil layer enables the pads to support very heavy loads, while the frictional resistance and the wear are low, owing to the fluid character of the friction. The pads have a supporting edge for both directions of rotation, and automatically rest against the appropriate stops; thus the bearing functions regardless of the direction of rotation. The Nomy bearing can be used in rolling mills. (D. 3.)

Non-Ageing Steels. Steels to which an addition has been made to the molten steel of an element that combines with the active carbon and/or nitrogen. The elements commonly used for this purpose are aluminium, titanium, and vanadium. The purpose of the addition is to prevent age hardening occurring in service. (K. 34.)

Non-Beat. A provision in the operating controls of a welding machine to insure completion of the operating cycle after the cycle has been initiated.

Non-Consumable Electrode. An arc welding electrode which does not provide filler metal, e.g. tungsten.

Non-Deforming Steel. (*Non-Shrinking Steel.*) A group of alloy steels which have the characteristic that they do not easily deform, or go out of shape, when heated. This property renders them suitable for the production of precision tools such as *dies* and gauges. Non-deforming steel contains from 1% to 1·75% manganese, with or without chromium or other alloying elements. The carbon content is the same as in tool steels of the same grade. The steels are oil-hardening, and impurities are kept as low as possible.

Non-Destructive Tests. Methods of examining the soundness of metals which do not involve the destruction of the specimen under test, as in

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Plate XI.—Non-destructive testing, using magnetic crack detection and ultrasonic methods.

mechanical testing. Such methods include, among others, *magnetic particle-*, *ultrasonic-* and *air-tests*, and *radiographic* examination. (See Plate XI.) (M. 18.)

Non-Electrolyte. A substance which does not conduct electricity when in solution; a substance not yielding *ions* in solution.

Non-Erosive Blasting. (See SEED BLASTING.)

Non-Magnetic Steels. Austenitic steels, such as 12% manganese, and 18/8 chromium-nickel steels, which have magnetic permeability values approaching unity under normal conditions. Cold-working may, for example, render the steels slightly magnetic.

Non-Metallic Inclusions. (See INCLUSIONS.)

Non-Piping Steel. (See BALANCED STEEL.)

Nonpressure Thermit Welding. A *thermit welding* process wherein coalescence is produced by heating with superheated liquid metal resulting from the chemical reaction between a metal oxide and aluminium, without the application of pressure. Filler metal is obtained from the liquid metal. (A. 37.)

Non-Shrinking Steel. (See NON-DEFORMING STEEL.)

Non-Sizing. (See RUNNING OUT.)

Non-Sparking Tools. The two most common non-sparking alloys are aluminium bronze and beryllium-copper, the former being used most frequently for tools which are not required to withstand extreme service conditions. Beryllium-copper, containing up to about 2·5% beryllium, is used for tools requiring a higher resilience than can be obtained in a bronze and for applications demanding toughness combined with maximum hardness, such as for drills and chisels. The outstanding characteristic of the beryllium-copper alloy is that it can be hardened by heat treatment; thus, articles may be shaped and machined in the soft condition and then heat treated to the desired strength and hardness, e.g., a Brinell hardness of from 300 to 400 with a tensile strength of 40 to 60 tons per sq. in.

Norbide. A proprietary material (boron carbide, B_4C), said to be second only to the diamond in hardness. It is inert towards chemical media and resistant to oxidation. Norbide is manufactured from carbon (as coke) and boric acid. The latter is heated to render it anhydrous, and the materials are fused in an electric resistance furnace at 2660° C.; crystalline boron carbide results. In powdered form it finds use as an abrasive; in the moulded form it resists abrasion very well, and may be used for sand-blast nozzles, extruding dies, etc. (I. 49.)

Nordac Coating. An acid resistant rubber lining for prescaling tanks.

Norelco Fluorescence Analysis. A method of analysis in which the specimens are exposed to an intense beam of exciting X-radiation. This results in individual X-radiations being generated by elements susceptible to such excitation. The combined radiations representing the various constituents are passed through a special collimating system to a crystal which serves as an analyser and which, by proper positioning, reflects each of the individual radiations at a specific angle. Intensities are measured by means of a Geiger counter, arranged together with a crystal and its angulating mechanism on a specially designed goniometer. Data obtained from this system can be evaluated in terms of percentages of the elements present. (M. 87.)

Normal Calorie. The 15° calorie. (See CALORIE.)

Normal Induction. (See INDUCTION, NORMAL.)

Normal Induction Curve. (See INDUCTION CURVE, NORMAL.)

Normal Solution. A solution of a reagent used in volumetric analysis, such that one litre of the solution contains one gram equivalent of the reagent.

Normal Steels. Steels in which the pearlite is completely laminated. (Cf. ABNORMAL STEELS.)

Normalizing. Heating to, and if necessary holding at, a suitable temperature, i.e. about 50° C. above the *transformation range*, followed by cooling in still air at room temperatures so that moderately rapid cooling occurs, the object being to eliminate internal stresses, refine the grain size, render the structure more uniform, and improve the mechanical properties. It is used specially for large forgings or castings, which cannot be quenched and tempered and to produce a more uniform structure than exists in untreated pieces. (See Plate VIII (b).)

Normality. A term used for expressing the concentration of solutions. (See NORMAL SOLUTION.)

Normametre. A hardness testing instrument of the rebound type employing a small hinged hammer which falls through a quadrant on to the surface of the specimen under test. The hardness is measured from the position of the rebound.

Norsk-Staal Process. A process for the direct production of iron sponge

A mixture of carbon monoxide and hydrogen is used as the reducing agent. The equipment consists of three vertical ovens, for preheating, reducing and cooling the charge, and apparatus for regenerating the spent gases. The ore is contained in a series of muffle trays, each tray holding about 3 tons of ore. These trays pass down through the preheating oven, where the ore is heated to 1000°, and are then transferred to the reducing oven, where they are raised slowly through and against the downward gas current, then transferred to the cooling shaft, and slowly lowered down it. The transfer of a tray from one oven to another is made without contact with air. The ore is preheated in the first oven by part of the gases from the reduction oven, and the sponge iron is cooled in the third oven to 50° by cold gas from a gas holder. (B. 127.)

Nose. (*a*) A term sometimes applied to a mass of frozen metal round the inner end of a *tuyere*. (*b*) The constriction of a Bessemer converter near the top. (*c*) The thin edge of a wedge or wedge-shaped article.

Notary Public. A person authorized to attest or certify documents in order to give them validity in countries outside the United Kingdom. In England, a notary is usually a solicitor whilst in Scotland a notary must be a law agent.

Notch Brittleness. Undue liability to fracture in a brittle manner at notches, fillets and grooves, as indicated by the notched bar test. (See NOTCH SENSITIVITY.)

Notch Effect. Notches, i.e. sharp re-entrant angles in metals whether present as features of design, or inherent in the metal.

Notch Fatigue Factor. The ratio between notched fatigue strength and unnotched fatigue strength.

Notch Impact Value. Fracture under heavy loads often originates in service at the base of a sharp fillet or notch. The resistance of the steel to the start and propagation of a crack at the base of a standardized notch is measured by the amount of energy absorbed by the specimen as it fractures under a hammer blow delivered by a standard pendulum. The two most commonly used notched bar impact test specimens, are the *Izod* which contains a 45° V notch, and the *Charpy* which contains a special notch of the keyhole type. In general, the Izod V notch imposes a more severe notch effect upon the steel. The notch impact value is a measure of the notch brittleness, or conversely, notch toughness. (H. 39.)

Notch Saturated. A description sometimes applied to soft grey cast iron when the paths of weakness already existing along the large graphite flakes are so important that additional notches produce no further weakening.

Notch Sensitivity. The extent to which a material is incapable of retaining its *ductility* when notched; the extent to which it is unable to yield locally, so as to reduce high local stresses, as those arising from notches and other *stress-raisers*. The amount of ductility necessary to avoid failure depends upon the amount of *plastic flow* required to reduce the peak stress sufficiently. For different steels, notch sensitivity varies greatly. In general, the higher the *tensile strength*, the greater the notch sensitivity.

Notched Bar Test Pieces. Various forms of notch have been adopted by different engineers. (See CHARPY, IZOD, FRÉMONT, AMSLER, GUILLERY, etc.)

Notched Bars. (See NOTCHED INGOTS.)

Notched Ingots. (*Notched Bars.*) Cast metal in the form of small ingots or bars which can be fairly easily broken at the notches to give smaller pieces suitable for remelting (e.g. aluminium in bars weighing 2 lb. notched to give 4 oz. pieces approximately).

Novopress Reheating Furnace. A furnace fitted with a new type of single point control, by which a single movement of a hand wheel regulates the gas and air and automatically opens the flue damper. The correct proportion of gas and air under all conditions of heating is ensured by a gas and air proportioning valve. Recuperators of special design are embodied which transfer the waste heat from the flue gases to the incoming low-pressure air. (I. 44.)

Nowel. (See DRAG.)

Nozzle. (See LADLE.)

Nozzling. Preparing a *hollow* for cold drawing by reducing the diameter at one end sufficiently to hold the head of a pin, the latter being used to pull the hollow through the die.

Np. Chemical symbol for *neptunium*.

N.P.A. National Production Authority (U.S.A.).

N.P.L. *National Physical Laboratory*.

N.P.L. Cupping Test. An oil-pressure cupping machine having a capacity of 5 tons per sq. in. The test piece is firmly clamped between the top face of the pressure chamber and a hard steel die, by screwing down the head. As the latter has to be removed each time the specimen is replaced, it is made in two parts, connected by a bayonet fitting. A leather packing ring rests in an angular groove machined in

the top face of the pressure chamber. The specimen is pressed down upon this by a corresponding annular tongue projecting from the face of the clamping die, which gives a high intensity of pressure on this ring when the head is screwed down tightly. The inner edge of the die is finished with a radius to prevent shearing of the test piece when the hydraulic pressure is applied. The depth of the cup and the oil pressure applied are automatically recorded. (G. 37.)

N.P.L. Spring Testing Machine. A machine for determining the resistance of leaves of motor lorry springs to reversed plane bending stresses. The specimen under test is rigidly clamped at one end, and a bearing block is fixed to the free end. In the bearing block runs a shaft, to each end of which are attached circular discs, each disc carrying equal out-of-balance weights. A motor causes the shaft, and attached discs, to rotate at a desired speed, the drive being transmitted through a spring coupling. Forced vibrations, synchronous with the motor speed, are thus given to the specimen, the amplitude of the vibration being dependent on the speed of rotation, on the masses attached to the specimen, and on the stiffness of the specimen. A pointer, attached to the free end of the specimen, moves over a graduated scale, and its amplitude is observed directly, using a telescope. The speed of working of the machine is 2400 r.p.m. (G. 36.)

N.P.N. Process. A modification of the basic Bessemer process. The main feature is the shortening of the blow by increasing the pressure of the blast as much as possible. Normally, the melt is cooled by the addition of scrap or iron ore but it is claimed that a fairly high temperature can be maintained without an undue increase of the nitrogen content, so that ladle sculls can be avoided. (G. 7.)

Nt. Chemical symbol for *niton*.

N.T.P. An abbreviation for normal temperature and pressure, i.e. 0° C. and 760 mm. of *mercury*. Also referred to as *S.T.P.*, i.e. Standard temperature and pressure.

N.T.S. An abbreviation used by draughtsmen, meaning "not to scale".

Nuance. The slight variation in *tensile strength* between different lots of steel, supposed to be identical, but which have, in fact, been subjected to slightly different conditions during manufacture.

Nuclei. Points at which crystals begin to grow during solidification. In general, these are minute crystal fragments formed spontaneously in the melt but frequently non-metallic inclusions act as nuclei. (See LABILE RANGE.)

Nugget. (*a*) A small mass of a metal such as gold or silver, as found in nature. (*b*) The weld metal joining the parts in spot, seam or projection welds.

N.U.M. National Union of Mine Workers.

Nursing. Very gentle working of *nesh* steel, in the preliminary stages of *forging*. (See also SADDEN.)

Nusbaumer Fatigue Testing Machine. A machine for the application of reversed plane bending stresses. The specimen is in the form of a long, flexible cantilever, and carries, at its free end, an armature piece. Direct current is applied in turn to each of these magnets, causing plane vibrations of the specimen. The current in the coils is adjusted so that the armature just touches each pole piece in turn, the armature being coated with tin foil to prevent sticking to the magnets. A constant speed motor drives a rotary contact breaker at 1800 r.p.m. (G. 36.)

N.W.S.A. National Welding Supply Association. (U.S.A.)

N.Y.S.E.M. *New York Society of Electron Microscopists.*

N.Z.S.I. New Zealand Standards Institute.

O

O. (*a*) Chemical symbol for *oxygen*. (*b*) Abbreviation for overhead welding position.

Oberhausen Processes. See page 473.

Objective. The lens, or set of lenses, opposite to the eyepiece in a microscope which forms an image of the specimen.

Occlusion. The retention or absorption of gases by solid substances. The term is applied particularly to the absorption or entrapment of gases by metals. *Palladium* will absorb nearly 1000 times its volume of hydrogen, whilst *gold* absorbs 46 times and nickel 15 times their respective volumes of hydrogen.

Octavo. (*8vo, Oct.*) Size of book or page given by folding sheets 3 times or into 8 pages. (See BOOK SIZES.)

Octaves. (See LAW OF OCTAVES.)

O.D. Outside diameter.

Oddsides. Semi-permanent moulds of plaster of Paris or dry sand, tarred and dried, used for repetition work in the foundry. In a *sand oddside*, a top half moulding box is partly rammed with a specially prepared mixture of sand and litharge, the *patterns* are embedded and ramming completed, after which the *joint line* is carefully struck so that part

of each pattern up to the joint line is hidden in sand. The pattern is then removed, the oddside moistened with core gum and then dried slowly in air. In a *plaster oddside*, a half mould of sand is first made with the patterns embedded, as for a sand oddside, and the joint line struck. On this a second half box is placed, the patterns being oiled to prevent the plaster sticking and then plaster of Paris is poured over the patterns. When this is hardened, the mould is turned over, and the top half, containing the sand, removed, all adhering sand being brushed from the patterns. The patterns are then withdrawn and the face of the oddside varnished. (R. 6.)

O.E.C.E. The Continental abbreviation for the *Organisation for European Economic Co-operation.*

O.E.E.C. Organization for European Economic Co-operation. (Referred to on the Continent as *O.E.C.E.*)

Oersted, H. (*a*) The c.g.s. unit of *magnetizing force.* (A. 28.) (*b*) The term has been suggested for the unit of magnetic reluctance but is very rarely used in the United Kingdom.

Oersted, Hans Christian. (1777–1851.) A Danish scientist, who isolated aluminium by reducing aluminium chloride with potassium amalgam, and demonstrated the connection between electricity and magnetism.

Off Gauge. Sheet or strip which is outside the specified gauge.

Off-Grade Metal. (See OFF-HEAT.)

Off-Heat. (*Off-Grade.*) A term used when the percentage of any element in the steel is outside the range of the specification.

Off-Iron. Pig iron which is not of the desired composition.

Offset. (*a*) (See MISMATCH.) (*b*) (See OFFSET YIELD STRENGTH.)

Offset Yield Strength. The stress at which the stress-strain curve departs from linearity by a specified percentage of deformation (*offset*).

Offtake. A large opening at the top of a *blast furnace* through which the gases pass to the *downtake.*

Off-Time. In resistance welding, the time during which the electrodes are off the work.

O.H. (*a*) Oil hardened. (*b*) *Open Hearth.*

Ohm. Unit of electrical resistance. That resistance through which a potential difference of one *volt* will produce a current of one *ampere*. The international ohm is defined as the resistance of a column of mercury at 0° C., 106·3 cm. in length, and having a cross-sectional area of 1 sq. mm. (i.e. a mass of 14·4521 gms.).

Ohm, Georg Simon. (1787–1854.) A German physicist who carried out researches in electricity, leading to *Ohm's law.*

Ohm—Mile Constant. The electrical resistance of wire expressed in *ohms* per mile multiplied by the weight in pounds per mile.

Ohm's Law. This law states that the voltage drop produced by the current is proportional to the magnitude of the current. The resistance is represented by the voltage divided by the current, and remains constant with unchanged temperatures except in the case of special materials.

Ohmmeter. An instrument for measuring the electrical resistance of conductors and insulating materials (insulants) and provided with a scale graduated in *ohms* or *megohms.*

Oil and Whiting Test. One of the oldest methods used for detecting fine cracks. It consists in applying a penetrating solvent such as paraffin or a very low viscosity oil to the part being tested, wiping the excess solvent off the surface and then painting with a mixture of whiting and a thinner. As the thinner dries, the oil in the crack emerges and stains the whiting. Vibratory or other types of stressing can be employed to aid both the penetration and emergence of the oil. Penetration can be accelerated by immersion in hot oil or the parts can subsequently be heated to assist in forcing the oil out. (See also OIL POWDER METHOD.)

Oil Core. A core in which the sand is held together by an oil binder. (A. 26.)

Oil Hardened Steel. Steel which has been quenched by plunging it at the hardening temperature into an oil bath.

Oil Mist Lubrication. A system in which the lubricating oil is atomized by means of compressed air and the air-oil mixture or oil-mist is then piped to the bearing to be lubricated. (E. 66.)

Oil Mould. A mould in which the sand is held together by an oil binder. (A. 26.)

Oil Powder Method. A method similar to the *Oil and Whiting Test* in which penetrating oil is applied to the surface to be inspected for a period of one minute; it is then removed and the detecting powder dusted on. The tracery of the surface flaws appears as a sharply defined line on the dull white background of the detecting powder. (I. 12.)

Oil Sands. Sands which have been bonded with oil, e.g. linseed oil. Such sands are particularly suitable for the production of large cores where high strength and considerable permeability are required.

Oil of Vitriol. Concentrated sulphuric acid.

Old Horse. (See BEAR.)

Oleum. (See SULPHURIC ACID.)

Olivine. (See FORSTERITE.)

Olsen Brinell Hardness Tester. In this type of machine the load is applied to the work in less than two seconds by a slight movement of the operating lever. The continuous running motor driven rotary pump adds to its speed of operation, and the load is automatically checked at 3000 kg. or any other load up to this capacity for which the machine may be used by the aid of a pressure gauge. (M. 84.)

Olsen Cupping Test. A cupping test in which a piece of sheet, restrained except at the centre, is deformed by a standard steel punch with a hemispherical end. This test measures the depth of the impression required to fracture the metal. The test is similar to the *Erichsen* save that in the Olsen test the depth of cup is measured in thousandths of an inch as compared with hundredths of a millimetre in the Erichsen test.

Olsen Foster Fatigue Testing Machine. A machine for the application of reversed torsion in which calibrated springs are used to resist and measure the twisting moment applied to the specimen which is subjected to an amount of twist in one direction from the neutral position, and then to the same amount of twist in the opposite direction. The amount of deflection of the springs, and hence the magnitude of the twisting moment applied to the specimen, is given by the width of the diagram drawn by a pencil point. The number of cycles of twisting stress is shown by a counter. The machine can maintain a speed of 350 r.p.m. (M. 159.)

Olsen Impact Testing Machine. The machine is arranged to enable Charpy, Izod, and tension impact tests to be made without removal or addition of any tools or parts, and for use on 10 mm. square Izod and Charpy specimens, 0·45 in. diameter, round Izod specimens, and 6 mm. diameter tension impact specimens. The capacities are 120 and 264 ft. lb. A Change-o-matic head provides three striking surfaces, which are part of a shaft encased within the hammer. By loosening a screw and slipping the shaft out of a keyway, the head is free to be rotated to any of the three positions desired and locked again, for the three types of tests. (M. 45.)

Olsen Mohr Portable Brinell Tester. An instrument in which the specimen under test is fastened between the penetrator and a screw anvil, the pressure being applied to the indenter by means of a crank.

Omes Electroforging Process. In this method the material is heated by a low-voltage current which passes through the bar at the portion which is to be upset. When the desired temperature is reached, the bar is automatically fed by a hydraulic ram on to the face of an anvil until the required upset has been achieved, when the operation is automatically stopped. The headed bar is then reheated in a muffle furnace and forged to the required shape. It is claimed that aluminium-bronze and stainless steel blades can be produced by this method to within an accuracy of $\pm$ 0·006 in. (A. 19.)

O.N. Österreichischer Normenausschus i.e., Austrian Standards Committee.

O'Neill Ball Hardness Test. A method of making ball hardness tests on metals in which the specimen is placed upon a table which is propelled upwards by an electric motor; the specimen presses against the indenter, which is carried by a sliding piece in contact with a system of levers constituting a weighing machine. The table and specimen rise until the indenter is embedded in the latter to a predetermined amount, when a cover on the indenter (with a hole in its centre through which the indenter protrudes) makes contact with the specimen, so completing an electric circuit which reverses the motor and lowers the specimen. The load supported by the indenter at the moment of maximum penetration of the indenter is indicated by a non-return pointer traversing a scale. *Piling-up* is accounted for satisfactorily, but metals which *sink-in* cannot be tested with great accuracy. (O. 10.)

One-Minute Wire. A term applied in the U.S.A. to galvanized wire which will withstand immersion in a standard neutral copper sulphate solution for one minute without penetration of the zinc coating.

One-Piece Pattern. A solid *pattern* not necessarily made from one piece of wood. (A. 26.)

Onera Process. A method of producing a protective coating of chromium on steel. The process is based on catalytic transport of chromium by continuous equilibrium displacement in purely gaseous phase, which leads to perfectly homogeneous and regular layers. The specimens to be treated are laid between a chromium fluoride-generating medium and chromium broken into pieces. The whole is heated, preferably under a

hydrogen atmosphere or in a valve device. The medium is a mixture of powdered chromium, alumina and moist ammonium fluoride, or a mixture of ammonium fluoride and hydrofluoric acid. Ammonium fluoride or hydrofluoric acid reacts on chromium as the temperature reaches 500° to 600° to produce chromium fluoride, ammonia and hydrogen. When the temperature reaches 900°, chromium fluoride vapour reacts with iron as follows: $3Fe + 2CrFe_3 = 3FeF_2 + 2Cr$, but the FeF_2 is at once reduced by hydrogen to form iron and hydrofluoric acid. The hydrofluoric acid regenerates chromium fluoride by action on the chromium present. (G. 2.)

Onion's Alloy. (See LICHTENBERG'S ALLOY.)

Ono Fatigue Testing Machine. A machine devised for subjecting a specimen to reversed bending stresses combined with a steady torsional stress. A Wöhler machine of the four-point loading type is employed, the steady torsional stress being obtained by connecting one end of the specimen to an electrical absorption dynamometer. (G. 36.)

Oolites. A series of rocks consisting of small spherical or ellipsoid grains, resembling the hard roe of fish. These rocks include the oolitic limestone used for building and the oolitic-*haematites*, *-limonites* and *-siderites* which constitute valuable iron ores.

Open Annealing. (See BLACK ANNEALING.)

Open-Butt Pressure Welding of Steel. A process of butt-welding bar, tubes, and rails, in which an oxy-acetylene burner head, projecting flames on both sides, is placed between the surfaces to be welded. When fusion point has been reached, the burner is quickly withdrawn and the ends are forced together by mechanical pressure to complete the weld. (C. 33.)

Open Circuit Potential. The measured potential of a cell from which no significant current flows in the external circuit.

Open Circuit Voltage. The voltage of a welding circuit between the electrodes when no current is flowing. (B. 105.)

Open Die Coining. (See COINING.)

Open Die Forgings. Forgings that are made with open dies. The heated metal is forged between two flat dies, or dies that have a groove of simple shape, such as V-shape, half-round, or half-oval. This type of work may also be finished or sized between swages or similar tools which are struck by the dies.

Open Grain Structure. A defect wherein a casting, when machined, appears too coarse grained for the application. (A. 26.)

Open Hearth Furnace. The first furnace using the regenerative principle was built in 1858 by Sir William Siemens. About 1864, two Frenchmen, the *Martin brothers*, patented the process of melting pig iron and scrap in the Siemens furnace. It should be noted that whilst the term open hearth may refer to either the acid or basic process, unless otherwise stated, the use of the word *Siemens* is generally restricted to the acid process, whilst on the Continent the term *Siemens Martin* usually refers to the basic process. The furnace consists of a shallow rectangular hearth, approximately twice as long as it is wide, built in a pan of mild steel plate carried on beams supported on heavy foundations. The hearth is enclosed by walls, the front wall is provided with a number of charging doors, whilst in basic furnaces the back wall is usually sloping, the whole being covered with a roof. The *tapping hole*, which in stationary furnaces is plugged with refractory materials, is situated in the middle of the back wall. The air and fuel (gas or oil) are admitted independently through ports at either end of the furnace and these ports, which are connected by vertical flues with regenerator chambers, act alternately as inlet and exhaust ports. Combustion takes place across the furnace above the hearth, and the spent gases escape through the ports at the opposite end of the furnace, heating up the *checker brickwork* of the second pair of regenerators on their way to the stack. Every 10 minutes or so the flow is reversed so that the gas and air enter through the checker work just heated by exhaust gases. In the *basic open hearth process* the hearth is lined with rammed magnesite or dolomite and the slag is basic, i.e. it consists preponderantly of lime. In this method, sulphur and phosphorus can be largely eliminated from the steel, passing into the slag. The charge consists of pig iron, or of liquid iron direct from the blast furnace (*Hot Metal Process*), steel scrap, and considerable quantities of limestone. In the *acid open hearth process*, the furnace is built of acid materials, i.e. the walls, roof, hearth and ports are built of silica brick whilst ganister and silica sand form the bed of the hearth. Since neither sulphur nor phosphorus are removed in this process, high quality raw materials are essential. Pig iron and steel scrap are charged cold and

limestone and fluorspar are added as required to promote the fluidity of the slag. Iron ore additions are made, firstly to oxidize the silicon and manganese, these passing into the slag, which is essentially a lime-iron-manganese silicate, and finally to oxidize the carbon which escapes from the molten bath in the form of carbon monoxide, giving the bath the appearance of being on the *boil*. The refining is carried out under carefully controlled conditions, so that chemical equilibrium is maintained between the metal and its covering of slag. This is controlled chiefly by the visual appearance of *spoon samples* of metal, extracted from the bath at intervals, together with the appearance of the solidified slags. When the desired carbon content has been reached, the bath is *killed* by the addition of the requisite amounts of silicon and manganese alloys, and the furnace *tapped* into a *ladle* from whence the steel is poured into the ingot mould. The time occupied in the open hearth process from the commencement of charging to tapping is of the order of nine to twelve hours. Furnaces vary in capacity up to about 120 tons for the acid process, whilst in the basic process, furnaces of 250 tons are not uncommon. Many large basic furnaces are of the tilting type to facilitate slag removal. (See Fig. 8.)

Open Hearth Process. (See OPEN HEARTH FURNACE.)

Open Hearth Steel. Steel produced in an *open hearth furnace*.

Open Joint. A joint where the surfaces to be joined are spaced apart during the welding operation.

Open Joint Tube. Tube made by forming strip in the cold into the desired section, an appreciable gap being left between the edges.

Open Pass. In a rolling mill, the term employed when approximately one half of the pass lies in each roll and the joints between the two rolls, or the opening of the pass, lie in the centre.

Open Poured Steel. (See RIMMING STEEL INGOTS.)

Open Riser. (See RISER.)

Open Sand Casting. A casting produced in an uncovered mould.

Open Steel. Steel which has not been fully deoxidized before *teeming*.

Open Surface. Rough surfaced black plate caused by imperfections in the piece from which it was rolled.

Open Topped Housing. A *housing* in a rolling mill in which the top is formed by a separate unit and can be removed from the base.

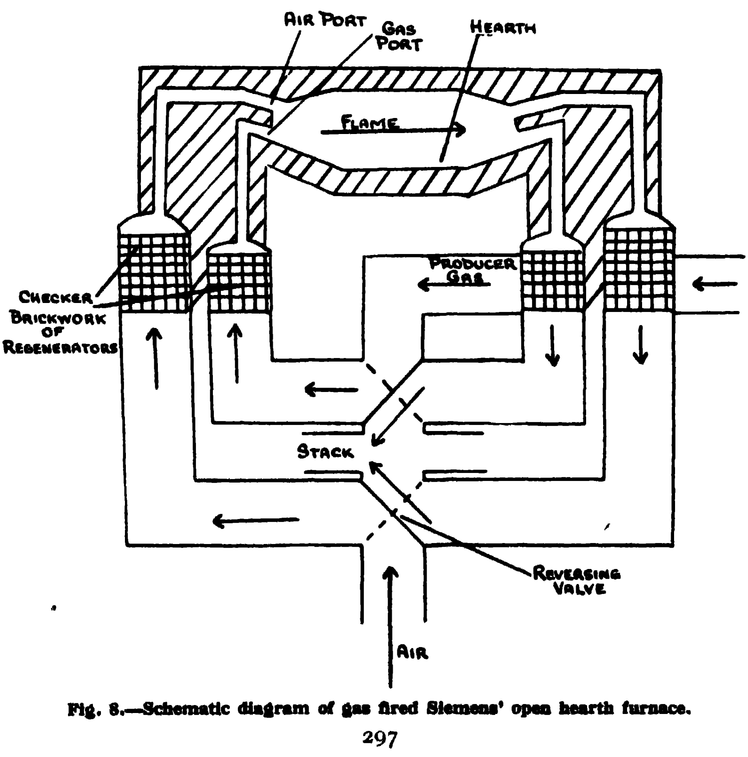


Fig. 8.—Schematic diagram of gas fired Siemens' open hearth furnace.

Opening. The separation of sheets in a mill pack.

Operating Stress. The stress to which a structural unit is subjected during service. (A. 27.)

Oppel Hardness Tester. This designation covers two types of instrument: type K 300 with a measuring range of 4 hardnesses from 50 to 300 kg./sq. mm., for testing steel, light metal, and bronze; and type K 50 for testing materials in hardness range from 8 to 50 kg./sq. mm. for precious metals, plastics, lacquer, etc. Both instruments are stated to be of the highest precision. They serve for checking not easily accessible positions in machines. (O. 14.)

Optical-Polarization Film. A method of measuring the surface stress in stressed structures without a model. A film of cellulose, resin or similar transparent material which becomes optically active under the effect of stress, is applied to the polished or silver-plated surface of the structural part to be examined. The article is then examined under polarized light. On the application of stress, the film becomes optically active and the intensity and direction of the surface stresses are shown up in exactly the same way as in the usual method using transparent models. (O. 15.)

Optical Dilatometer. (See LEITZ DILATOMETER.)

Optical Pyrometer. An instrument for the measurement of temperature through which the observer sights the heated object and compares its incandescence with that of an electrically heated filament whose brightness can be regulated. Optical pyrometry is based on the knowledge of the emissivity of the hot body.

Optimatic Pyrometer. An instrument for measuring the temperature of hot moving bodies in which two vacuum photocells are illuminated by two sources of radiation, namely, the surface under investigation and the filament of a comparison lamp. Any difference in the output of the two cells is applied to an amplifier which automatically adjusts the current in the filament until a brightness match is produced. The current in the filament is a measure of the source temperature and can operate a suitable recorder. (K. 50.)

Orange Peel Effect. (*Pebbling.*) An effect which arises from the roughening of the surface due to the coarse grain size, when a mild steel is stretched in tension beyond its elastic limit. (P. 29.)

Orbit. A path conjectured to be followed by *electrons* round the *nucleus*.

Order - Disorder - Transformation. (*Ordering.*) A reaction or transformation in certain solid solutions in which a random arrangement of solvent and solute atoms in the crystal is replaced by a regular or ordered arrangement of the different atoms on preferred lattice sites. Certain alloys solidify from the melt with their atoms arranged on a regular lattice, but with a quite random distribution of the atoms of either kind amongst the points of the lattice. At a temperature which may be hundreds of degrees below the melting point, what may be described as a second crystallization sets in. The atoms rearrange themselves by exchanging places until the two kinds are in regular arrangement. The transformation differs from an *allotropic change* because in the present case the same lattice points are occupied by the atoms before and after the change, whereas in an allotropic change one type of lattice turns into another. (See SUPERLATTICE.) (B. 78.)

Ordering. (See ORDER - DISORDER - TRANSFORMATION.)

Ore. A metalliferous mineral of economic value due to the fact that the metal may be extracted profitably.

Ore Down. (See PIGGING BACK.)

Ore Dressing. The concentration of raw ore and its conversion into a product from which the metal or metals can be recovered at a profit. (A. 27.)

Ore Preparation. A term applied to the processes of crushing, grading, blending, and screening, of ores. It may be further extended to include calcining and sintering.

Ore Process. A method of *malleablizing white iron* in which the castings are packed with a mixture of *haematite* into heavy cast iron containers which are then sealed with a luted lid and charged into the annealing furnace. (J. 12.)

Oreing Down. (See PIGGING BACK.)

Organic Chemistry. The study of the chemistry of carbon compounds, which form the basis of living matter.

Organization for European Economic Co-operation. (*O.E.E.C.*) This comprises the following Member countries: Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland, Trieste, Turkey and the United Kingdom. The organization came into being with the signing of the Convention for European Economic Co-operation on 16th April, 1948, when Member Governments pledged themselves "to combine their economic strength, to join together to make the fullest collective use of their individual capacities and potentialities,

to increase their production, develop and modernize their industrial and agricultural equipment, expand their commerce, reduce progressively barriers to trade among themselves, promote full employment and restore or maintain the stability of their economies and general confidence in their national currencies". Representatives of each of the Member countries meet daily at O.E.E.C.'s headquarters, the Chateau de la Muette, Paris, to discuss their economic problems and work out common solutions. The United States and Canada, although not members of the Organization, participate in its work.

Orientation. The direction of the axis of a crystal in relation to a certain surface or line; for example, the polished surface of a cleavage plane.

Orifice. A restricted opening of known dimensions, usually for the control or measurement of the flow of a fluid.

O.R.R. (See OVERSEAS RESEARCH REPORTS.)

Orsat Apparatus. A portable apparatus used for the analysis of gases.

Orthoclase. A mineral, consisting of silicates of potassium and aluminium.

Orthorhombic. A form having three axes intersecting each other at a right angle but all of unequal length. The rectangular and rhombic prisms, and the rhombic octahedron belong to this system.

Orton Cones. *Pyrometric cones* used in the U.S.A.

Os. Chemical symbol for *osmium*.

Osborn-Shaw Process. A precision casting technique consisting essentially of four stages: The preparation of an oversize model requiring only one contraction allowance, corresponding to that of the freezing metal; the preparation of bench master patterns cast in a hard plaster material; the production of accurate refractory moulds from the patterns, in an average time per mould of 3 minutes; and pouring. It should be noted that in this process no pre-casts in wax or other material are employed. (M. 42.)

Oscillating-Crystal Method. (For X-ray or crystal analysis.) Using a single crystal rotating at constant speed, but alternately in both directions through less than a complete rotation (usually much less). (A. 27.)

Oscillogram. (See OSCILLOGRAPHY.)

Oscillography. The observation, recording and measurement of the changing instantaneous values of the current or voltage in an electric circuit when these quantities are either alternating or transitory. The instrument used for the purpose is an oscillograph and the graphical record obtained is an *oscillogram*.

Oscilloscope. An instrument whereby the presence and/or nature of an electric current is revealed.

Osmiridium. (See OSMIUM.)

Osmium. (*Os.*) *Atomic weight* 190·2. *Specific gravity* 22·50. *Melting point* 2700° C. The heaviest of all known substances. It is harder than glass and quartz, but can be scratched by topaz. It oxidizes in air at about 950° C., with the formation of a highly poisonous tetroxide which is volatile at 100° C., and this effect, together with its scarcity, hinders commercial exploitation. Alloys of osmium with nickel or cobalt, also a naturally occurring alloy of osmium with *iridium*, known as *osmiridium*, are in use for pen nib tips, where their hardness and resistance to corrosion are particularly valuable. Osmium has been applied for the cladding of metals such as nickel, brass, copper and steel. Further, it forms a highly efficient *catalyst*, especially in hydrogenation.

Osmond, Floris. (1849–1912.) A French metallurgist who made an accurate study of the phenomena of the transformations occurring in the iron-carbon system. Later, his investigations were chiefly directed to the application of the microscope to the examination of the structure of iron and steel and to the perfection of methods of preparing, polishing, and etching the sections.

Osmondite. A term, now obsolete, first used by Heyn to designate a particular form of troostite produced by annealing steel containing 0·95% carbon at 400° C. for, whereas troostite is produced by hardening, osmondite results from annealing. It has been defined as that stage in the transformation of *austenite* at which the solubility in dilute sulphuric acid reaches its maximum rapidity. (M. 89.)

Osmosis. (From the Greek—Osmos—a push.) The migration of pure solvent through a membrane from the less concentrated to the more concentrated solution, a process tending to produce equality of concentration on both sides of the membrane. *Osmotic* or *solution pressure* is the excess of the pressure on the solution side of a semipermeable membrane over the pressure on the solvent side.

Osmotic Pressure. (See OSMOSIS.)

Ostwald's Dilution Law. The application of the law of mass action to the ionization of a weak electrolyte, i.e. in weak solutions the degree of electrolytic dissociation is proportional to the dilution.

Otwo Steel. (See p. 473.)

Outdoor-Exposure Tests. Corrosion tests in which the specimens are directly exposed to the elements. Panels may be hung vertically or supported at an angle; when the effect of sunlight is of interest, a rack of 45° facing south is commonly used.

Outer Corner. In a twist drill, the corner formed by the intersection of a lip and the flute face at the leading edge of the flute.

Outiclam. An alternative to brazing, consisting of suitably cut shanks to which carbide tips are secured by a washer and screw connection. (R. 20.)

Ovality. A term used for the defective shape of wire brought about by inaccurate positioning of the drawing die holder in relation to the drum.

Overageing. *Ageing* under conditions of time and temperature greater than those required to obtain maximum strength. (A. 27.)

Overbending. Allowance for *spring-back* when bending metal to a desired angle.

Overblowing. The use of excessive air blast in a Bessemer converter with resultant burning of the steel.

Overburden. The stratum of earth overlying the ore. In open pit mining this overburden has to be removed before mining of the ore can commence.

Overburdening. The addition of an excessive amount of ore and flux in proportion to coke in charging a *blast furnace*.

Overcut. (See CUT.)

Overdraft. The tendency of metal to curve upwards when leaving the rolls. This is caused by the lower peripheral speed of the upper roll, the bottom roll being so designed that its diameter is very slightly larger than that of the upper roll.

Overdrawing. (See HOLLOW DRAWING.)

Overfill. (See FLASH.)

Overflows. Separated cavities cut into the face of die-casting dies adjacent to the main cavity and connected to it by means of a channel which permits molten alloy to flow into it directly from the main die cavity as the latter fills. (B. 21.)

Overhang. The extension of the end surface of the *cope* half of a *core print* beyond that of the *drag* in order to provide clearance for the closing of the mould. (A. 26.)

Overhead Weld. A weld made in a surface lying horizontally or at an angle not more than 45° to the horizontal, the weld being made from the under or bottom side of the parts joined. (B. 105.)

Overheating. Heating a metal or alloy below the temperature at which *burning* occurs, but to such a high temperature that deterioration of properties results. The condition is characterized by the fracture which presents a dull facetted surface and by the appearance of a characteristic network on etching polished sections with sulphuric/nitric acid reagent. Steels subject to slight overheating may be rectified by heat treatment but severe overheating cannot be eliminated by any commercially applicable method.

Overlap. (*a*) An imperfection at the toe of a weld caused by an overflow of weld metal on to the surface of the parent plate without fusing to the latter. (*b*) (See LAP).

Overnight Test. A method for determining the endurance limit, which is based on the principle that, below the endurance limit, cycles of repeated flexure increase the endurance limit and presumably the tensile strength, whilst above the endurance limit, cracks begin to develop, and reduce the tensile strength. The Rockwell hardness of the specimens is determined. They are then subjected to the specified number of cycles of stress in a rotating beam machine, which usually requires some 15 to 16 hours. After this, the specimens are pulled as tension specimens. Those breaking before the end of 1,400,000 cycles are credited with zero tensile strength. Making corrections proportional to the hardness figures, the data are plotted with the stresses applied for 1,400,000 cycles as ordinates and tensile strength after this period as abscissae. The endurance limit is taken as the ordinate corresponding with the maximum abscissa on this curve. (M. 161.)

Overpickled. Steel having a roughened surface caused by excessive chemical attack in the pickling operation.

Overpoled. (See POLING.)

Overseas Economic Surveys. Reports on the industrial resources and markets of countries overseas. Published by H.M. Stationery Office.

Overseas Research Reports. (*O.R.R.*) On sale at the D.S.I.R. Technical Information and Documents Unit, Lacon House, Theobalds Road, London, W.C.1.

Overseas Science Students Association. Affiliated to the *Society for Visiting Scientists*, and at the same address.

Overseas Trade. (See TRADE ENQUIRY OFFICE.)

Oversize Powder. In powder metallurgy, the particles coarser than the maximum permitted by a given specification.

Overspeeding. (See SURE FIRE TESTING.)

Overstressing. (*a*) Permanently deforming a metal by subjecting it to stresses that exceed the *elastic limit*. (*b*) The term as used in *fatigue testing* relates to the action of submitting a test piece to a cyclic load above that of its normal *fatigue strength* before subjecting it to a lower stress.

Overvoltage. The difference between the potential at which a gas, especially hydrogen is evolved from a solution and the potential of a reversible electrode of the same gas in the same solution. A metal of low overvoltage can increase corrosion, whereas a metal of high overvoltage may be used to inhibit the corrosion of a base metal. (G. 26.)

Overwork. Excessive cold work which may lead to *season cracking*, *hollow drawing* of bars, or the *exfoliation* of sheets. It can be avoided by restricting the amount of cold work performed at each stage, and by intermediate annealing.

Owen's Jet Dust Counter. An instrument similar to the *Konimeter* but differing in that the air to be sampled undergoes humidification prior to being blown through the jet. The velocity of impingement is about 200 to 300 metres per second and the jet is rectangular instead of circular. The prior humidification of the air causes condensation of moisture upon the dust particles by super-saturation due to the pressure-drop at the jet, and so assists in the deposition and retention of the particles on the slide. The *Bausch and Lomb dust counter* is the American counterpart of this instrument. (B. 128.)

Oxford-Airey Machinability Tester. The machine consists of a weighted pendulum, the shaft of which carries, on the one side, a pointer moving over a scale graduated in degrees, and on the other a cutting tool. The pendulum assembly can be moved both vertically and horizontally with respect to the base plate on which the test specimen is firmly clamped, in order to give varying depths and feeds of cut. Calibration of the machine is carried out in the following manner: the height to which the pendulum rises when allowed to fall freely from the position of maximum potential energy is taken as the zero, and the height to which it rises after cutting the test piece gives a measure of the energy absorbed during cutting. The type of cut is similar to that produced by a milling cutter, and, consequently the results, while they should be applicable to milling, are not necessarily true for all machining operations. (K. 18.)

Oxford Impact Tester. The aim of this machine is to eliminate any possibility that energy may be transferred to earth by shock, on the grounds that energy so transferred would be erroneously included in the estimated work of fracture. To this end, the rigid pendulum of the *Izod* and *Charpy* machines has been replaced by entirely separated anvil and striker, each suspended by flexible wires in such a way that it moves without rotation in a circular path. At the moment of impact all the wires are in vertical planes and hence at right angles to the (horizontal) line of the blow; since in addition this line passes through the centres of gravity of both anvil and striker, the wires can transmit no shock to earth. The other principal novelty in the Oxford technique is the employment of four-point loading whereby the notched section is subjected to bending action unaccompanied by shear. (E. 41.)

Oxidation. The chemical combination of elements with *oxygen*. In metallurgy, it implies the combination of alloys, or their constituents, with atmospheric oxygen. For instance, the slow combination of iron with atmospheric oxygen at normal temperatures is *rusting*, the much faster combination at elevated temperatures is *scaling*, and the extremely rapid combination at temperatures of incipient fusion is *burning*. (See also DECARBURIZATION.)

Oxidation Method of Determining Austenitic Grain Size. The oxidation method depends on the fact that when steels are heated in an oxidizing atmosphere, oxidation takes place in part preferentially along the grain boundaries. A common procedure is, therefore, to mirror polish the test specimen, heat it in air and then repolish by grinding down the surface sufficiently (about $\frac{1}{32}$ in.) to remove any severely decarburized material, but not far enough to remove all the oxide penetration around the grains. For etching, 10% solution of hydrochloric acid in ethyl alcohol is used.

Oxidation Resistant Steel. Steel designed by its composition and treatment to resist progressive or important attack by oxygen at elevated temperatures.

Oxidation Tints. The colouration of a bright steel surface by the formation of oxide films. (See TEMPER COLOURS.)

Oxide. A compound of oxygen with another element. Oxides are divided into four groups: basic oxides, acidic oxides, amphoteric oxides and peroxides.

Oxide Films. Thin layers of oxide produced on the surface of metals and alloys in air or under other oxidizing

conditions. Oxide films formed at normal temperatures on such metals as chromium or aluminium or on stainless steel, attain a thickness of about 50 *ångströms* and then virtually stop growing unless damaged, whereupon they re-form. It is assumed that the formation of the films is due to the diffusion of metal ions and electrons through the oxide layer, and their reaction with the oxygen at the oxide-gas interface. The limitation of the film thickness is due to the fact that electrons can penetrate to a distance of the order of 50 ångströms without receiving energy of excitation, but cannot pass through thicker layers unless they receive energy from heat. (M. 169.)

Oxide Printing. A method of recording the distribution of oxide inclusions in steel which consists in placing a sheet of photographic paper, previously soaked in a 1 to 20 aqueous solution of hydrochloric acid, in contact with the surface of the specimen for a period of one to two minutes. The paper is then removed and developed in a 2% solution of ferricyanide until a bluish colour appears; it is washed, fixed in hypo, rewashed and dried. (T. 18.)

Oxide Replica Technique. A method for the electron microscope examination of stainless steel and high nickel alloys. The oxide film is produced on the metal surface by oxidation in a molten nitrate solution and is chemically stripped from the base metal by a bromine-methanol solution. Replicas of this type were used to study deep-etched structures, preferential etch attack, and secondary phases in austenitic and ferritic stainless steel and in nickel. (M. 66.)

Oxidized Pig Iron Process. (See ROHEISENZUNDER PROCESS.)

Oxidizing. (*a*) A colloquial term applied to the production of a film, generally a sulphide, on a metal which is subsequently relieved for decorative purposes. (*b*) (See OXIDATION).

Oxidizing Conditions. Referring in general to those conditions under which metal reacts with oxygen in its environment to form a surface oxide.

Oxidizing Flame. A flame having oxygen in excess of that required to produce a *neutral flame.*

Oxweld Automatic Process. A process of pressure butt welding rails. It consists of bringing the properly prepared ends of two rails, in a suitable machine, clamping them in accurate alignment, compressing the ends together with continuously applied hydraulic pressure, while a series of oxy-acetylene flames are applied all round the rail ends at the point of juncture. This heat is applied continuously until the metal of the rails reaches the plastic state. The joint is not a fusion weld, but a weld in which the action takes place while the metal is, metallurgically speaking, in the solid state. A portion of the excess metal at the weld, which has become upset, is then removed, and the weld zone is reheated to above the critical temperature and allowed to cool in a normalizing operation which refines the grain. (A. 7.)

Oxweld Cutting Process. A flame-cutting process in which an iron-rich powder is automatically added to the cutting oxygen stream. This releases large quantities of heat and creates superheated particles of iron oxide. The burning of the iron powder permits the cutting oxygen to oxidize the base metal. The process is designed for cutting stainless and other steels, difficult to cut by the ordinary process and the quality of the cut compares favourably with that obtained in plain oxy-acetylene cutting of carbon steels. (W. 25.)

Oxy-Acetylene Cutting. An oxygen cutting process wherein the severing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures, the necessary temperature being maintained by means of gas flames obtained from the combustion of acetylene with oxygen. (A. 37.)

Oxy-Acetylene Flame Hardening. (See FLAME HARDENING.)

Oxy-Acetylene Pressure Welding. A process effected either by butting the matching surfaces of the two sections under nominal pressure, heated by means of multiple small oxy-acetylene flames to a temperature of about 1200° C. and upsetting to a controlled degree, or by leaving a space between the matching surfaces during heating to the desired temperature and then applying pressure. The completed weld has a definite bulge or upset which can provide useful reinforcement. (L. 58.)

Oxy-Acetylene Scarfing. (See SCARFING.)

Oxy-Acetylene Welding. A gas welding process in which fusion is effected by heating with a gas flame obtained by the admixture of acetylene with oxygen in a suitable torch and ignited to produce an impinging flame. The use of pressure and/or filler metal is optional.

Oxy-Arc Cutting. A method of cutting, piercing, and gouging, any metal or alloy using an electric arc and a stream of oxygen, both conducted to the point of operation through a flux-coated

tubular electrode or rod. The dimensions and composition of the steel core determine the width, depth, speed and quality of cut. The coating stabilizes the arc, seals the oxygen jet to the work, insulates the core from the work and fluxes the oxides from the cut. (C. 6.)

Oxy-City Gas Cutting. An oxygen cutting process wherein the severing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures, the necessary temperature being maintained by means of gas flames obtained from the combustion of city gas with oxygen. (A. 37.)

Oxy-Ferrolene De-Seaming Process. An application of the *Ferrolene* gas-fuel enrichment process, which impregnates ordinary coal-gas or coke-oven gas with the vapour of Ferrolene liquid. The resultant mixture is known as Ferrolene gas, which can be burned with oxygen to produce an intense flame of very high temperature. This high-temperature flame has been used to remove surface cracks from billets, ingots, slabs and blooms. It is claimed that the surface left after dressing with *Ferrolene* is smoother and less ridged than that which is left by acetylene, and the surface hardening caused by the dressing flame is less marked.

Oxy-Hydrogen Cutting. A metal-cutting process which is effected by the chemical reaction of oxygen with the base metal at elevated temperatures, the necessary temperature being attained by a flame produced by the combustion of hydrogen with oxygen.

Oxy-Hydrogen Welding. A gas-welding process wherein coalescence is produced by heating with a gas flame or flames obtained from the combustion of hydrogen with oxygen, without the application of pressure and with or without the use of filler metal. (A. 37.)

Oxy-Kinetic Flame Cutting Process. The process consists in charging the jet of oxygen with solid particles, thus strongly increasing its kinetic energy, and in expelling the slag by purely mechanical action. Favourable test results have been obtained with 18/8 stainless steels and special steels of still higher alloy content, as well as with cast iron. From a hopper, the particles fall through a regulating valve into a small receiver, where the stream of oxygen picks them up. The great speed of the oxygen accelerates the flow of the particles until they leave the burner at a high velocity. The burner itself resembles the ordinary flame cutting burner, except that a special nozzle has been introduced to withstand the abrasive action of the particles. The operation is the same as for the normal flame cutting process: first priming and heating up, then cutting with the high-pressure jet charged with particles. The burner may be moved by hand or automatically. (L. 19.)

Oxy-Natural Gas Cutting. A metal-cutting process effected by the chemical reaction of oxygen with the base metal at elevated temperatures, the necessary temperature being attained by a flame produced by the combustion of natural gas with oxygen.

Oxy-Propane Cutting. A metal-cutting process effected by the chemical reaction of oxygen with the base metal at elevated temperatures, the necessary temperature being attained by a flame produced from the combustion of propane with oxygen.

Oxy-Propane Welding. A gas welding process in which fusion is effected by heating with a gas flame obtained by the admixture of propane with oxygen in a suitable torch and ignited to produce an impinging flame. The use of pressure and/or filler metal is optional.

Oxygen. (*O.*) *Atomic weight* 16·00. *Atomic number* 8. An odourless, invisible gas, forming approximately one-fifth of the atmosphere. It is chemically active, burning and respiration both involving combination with oxygen. Because it supports combustion, oxygen finds wide application in industry. Its employment with fuel gas, such as acetylene, gives a flame temperature exceeding that of any other gas combination. Such flames are used for a wide variety of purposes as, for example, welding and cutting of metals. Oxygen liquefies at $-183°$ C., and it has many applications in liquid form, such as the shrinking of metallic parts. Cylinder liners, for example, require an interference fit in the block, and brief immersion in liquid oxygen suffices to shrink them so that they may be inserted with ease, and upon return to normal temperature and size, the required fit is obtained. As regards steel-making practice, oxygen is injected into steel baths in open hearth and electric furnaces by means of lances or jets, to assist in the melting down of the scrap and, during the refining period, to speed up the carbon reduction. In the production of stainless steel, the use of oxygen, followed by reduction of chromium from the slag with silicon, and/or aluminium, allows the carbon to be removed and permits higher

percentages of stainless scrap in the furnace charge. (See also OXYGEN IN STEEL.)

Oxygen-Bomb Calorimeter. The heats of combustion of solid and liquid fuels are usually measured in an oxygen-bomb calorimeter. This instrument consists of a metal calorimeter vessel filled with water, in which are immersed a constant-volume bomb, a stirrer, and a thermometer for measuring the water temperature. The temperature rise of the calorimeter, produced by the combustion of a weighed sample of fuel with oxygen in the bomb, is a measure of the heat of combustion of the fuel. (F. 14.)

Oxygen-Flux Process. A process of flame-cutting, similar to the oxy-arc process, but with the addition of a non-metallic flux to the oxygen stream.

Oxygen Impingement Process. A process in which pure oxygen is blown down on to the bath in a converter-like vessel. It is claimed that the process refines pig iron so that blown steel needs no deoxidizing additions, and that it is cheaper than the usual open hearth process. (S. 154.)

Oxygen in Steel. Oxygen is soluble in liquid iron as ferrous oxide, FeO, to the extent of over 1.0%. If liquid steel, containing carbon and oxygen is allowed to solidify, the ferrous oxide reacts, with carbon to give carbon monoxide, CO. This is not appreciably soluble in the steel and leads to unsound, *wild* or gassy ingots. If, however, the steel is *killed* or deoxidized, that is, treated with elements such as manganese, silicon, aluminium, etc., the ferrous oxide will react with the element to give the corresponding oxide. A killed steel, therefore, contains oxygen combined as manganese oxide, silica, alumina, etc., these oxides usually being present as complex silicates or aluminates, and forming *non-metallic inclusions*. The amount of oxygen in killed steel varies; a steel made by the *basic electric process* contains about 0·002% to 0·005% oxygen; acid *open hearth steel* may contain up to 0·015% oxygen, while *Bessemer steel* may contain large amounts. (See also OXYGEN.)

Oxygen in Steelmaking. (See OXYGEN.)

Oxygen Lancing. (*a*) A method of cutting concrete, etc., which employs a lance consisting of a long steel tube tightly packed with a number of steel rods through which oxygen is forced under pressure. The end of the lance is heated to redness and the oxygen turned on, whereupon the temperature of the steel rod is raised to melting point, and the molten iron reacts with the sand and other oxides in the concrete, so forming a liquid slag which flows away under the heat of the flame from the end of the lance. (*b*) In steelmaking (see OXYGEN).

Oxygen Recorder. (See MAGNETIC OXYGEN RECORDER.)

P

π. (*Pi*) = 3·1416. The ratio of the circumference to the diameter of a circle.

P. (*a*) Chemical symbol for *phosphorus*. (*b*) Trade abbreviation for *pickled*.

$P_{0·05}$ (See MARTENS HARDNESS.)

P.A.C. Process. A precision casting process for producing tools, dies or other parts very close to final shape so that rough machining is eliminated.

Pack. A number of steel sheets piled together for *pack rolling* into a lighter gauge.

Pack Annealing. (See BOX ANNEALING.)

Pack Carburizing. A process consisting essentially of heating articles at a suitable temperature in containers in which the work is surrounded by a compound whose purpose is to furnish carbon for absorption by the steel. Most carburizing compounds are of the charcoal-coke or coke type, and both contain up to 15% to 20% alkali carbonates to act as *energizers*. The charcoal-coke compound generally contains about three parts charcoal to one of coke, whilst in the coke type compound, part or all of the charcoal is replaced by coke. (F. 48.)

Pack Hardening. The usual *case hardening* process. (See also PACK CARBURIZING.)

Pack Rolling. (*Ply Rolling.*) A method of hot rolling in which two or more sheets are heated and given successive passes through the rolling mill until the required thickness is obtained. The individual sheets are then separated.

Package Mill. A small rolling mill which rolls and coils narrow strips of anything from copper to stainless steel at rates of up to 2000 ft. per min.

Packaging. (*a*) Refers, in the U.S. steel industry, to the most economical and safest method of grouping finished or semi-finished steel products for loading and transporting to the customer. (*b*) (See PAPER, PACKAGING, and ALLIED TRADES ASSOCIATION, Appendix V.)

Packing. (*a*) The term as used in U.S.A. foundries, applies to sand, gravel, mill scale or other similar material used to support castings packed in annealing

pots, to prevent possible warpage. (*b*) The operation of packing. (See TAMPING.)

Packing Material. In powder metallurgy, any material in which *compacts* are embedded during the *pre-sintering* or *sintering* operation.

Pad. (*a*) A press operation used to obtain accurate alignment of the various parts of a forging, or to improve the surface. (*b*) A local deposit of weld metal laid on a surface by a *fusion welding* process. (*c*) A shallow projection on a casting, distinguished from a *boss* or *lug* by shape and size. (*d*) A safety device in the form of a cast iron disc, placed between the screw and the chock in a *cogging mill*.

Pad Welding. A term sometimes applied to the building up of worn parts by welding.

Padding. The process of adding metal to a cross section of a casting wall, usually extending from a riser, to insure adequate feed to a localized area where a shrink would occur if the added metal were not present. (U.S.A.) (A. 26.)

Paddles. (See BRICKING UP.)

Pahlitzsch Method. (See DUAL COOLANT METHOD.)

Pairs. Two sheets hot rolled at the same time.

Palladium. (*Pd.*) *Atomic weight* 106·7. *Melting point* 1552° C. A lustrous white and very malleable, ductile metal, which can readily be fused, cast and worked. *Specific gravity* 12·0. The metal is usually melted on a lime hearth and cast into graphite moulds, various precautions being necessary to avoid gas absorption, to which this metal is very liable. At low temperatures, palladium readily absorbs hydrogen, to the extent of up to 1000 times its own volume at room temperature. It finds considerable use as a catalyst and in the purification of hydrogen, for the cladding of nickel for contacts in the speech circuits of tele-communication systems, for dental alloys and in jewellery. (S. 8.)

Pallaplat Thermocouple. (See THERMOCOUPLE.)

Palm End. (See ROLLING MILLS.)

Palo-Travis Analyser. A sedimentation apparatus for the determination of particle size, based upon the settling of powder through a long sedimentation tube filled with liquid. The instrument consists of the sedimentation tube, a smaller reservoir at the top joined to the tube through a large-bore stopcock, and a calibrated capillary mounted concentrically at the bottom of the tube. An initially concentrated suspension of powder is allowed to settle in the sedimentation tube and a small portion of the powder is diverted into the capillary. Particle-size distribution data may be calculated from observations of the height of powder in the capillary at a predetermined time schedule based on *Stokes' Law*. Large samples are required.

Pane. (See PEEN.)

Pantograph. (*a*) A device by means of which a point is made to copy, on any desired scale, the pattern traced by another point. (*b*) A sliding type of current conductor used for maintaining contact between electric trains, etc., and an overhead contact wire.

Paper Quantities. 24 sheets = 1 quire; 20 quires = 1 ream. Paper supplied for printing purposes usually contains 500 sheets to ream. In some cases 516 sheets are supplied.

Paraglyph Printing. A method of reproducing radiographs. Beginning with the original negative, a positive is made on film by contact. The proofs are then placed in contact with paper, superimposing on the printing box the negative and the positive in slight misalignment. As a result, a relief effect is produced, equivalent to a photograph on which a radiograph is superimposed. (G. 42.)

Parallel Growth. A homogeneous aggregate in which the crystals are uniformly oriented, so that the corresponding axes of all crystals are parallel.

Paramagnetic Material. A material having a *permeability* which is slightly greater than that of a *vacuum*, and which is approximately independent of the *magnetizing force*. Such material tends to move from the weaker to the stronger portions of a magnetic field, and to set with its greatest length parallel to the direction of the field.

Parameter. The term as applied to crystals refers to the characteristic magnitude defining the unit cell or the position of a point within it. The edges of the unit cell, a, b, c and the angles, α (between b and c), β (between c and a), γ (between a and b), are its parameters. The edge of the unit cube, a_0, is the single parameter of a cubic lattice. When the fractional co-ordinates of a point within the unit cell may vary, the values of these fractions (x, y, z) are parameters of the structure. (See also AXIS.)

Parcel. A coil or bundle of wire of unspecified quality.

Parco Compound. A zinc iron phosphate coating for iron and steel.

Parco Lubrite Process. A method for treating cast iron and steel parts of Diesel engines in speeding up the

running-in process of mating parts, with a reduction of scuffing during this period and of subsequent wear. The treatment involves an acid etching process in which a non-metallic coating is formed principally of iron and manganese phosphates. Microscopic examination of the dull matt-finished surface reveals countless etched pores which act as tiny oil reservoirs. Many of these remain even after the coating has worn away. Meanwhile the surface has been brought to the desired finish, and wear will be retarded. (D. 30.)

Parco Powder. A manganese-iron-phosphate coating for iron and steel.

Parent Metal. The metal or alloy of the parts to be welded.

Parkerizing. A method of producing a protective phosphate coating on ferrous metals. Parker A treatment depends on the immersion of the iron or steel to be heated in a solution of acid manganese phosphate. The Parker D process is a modification of the A process, which employs a solution of acid zinc phosphate with a nitrate ion as accelerator.

Parlanti Casting Process. A gravity die casting process using dies of aluminium, which has a much greater heat transfer rate than other material commonly used for casting dies or moulds. The quantity of heat dissipated or transferred can therefore be regulated by increasing or decreasing the surface area of the die, varying the outside form, or by radiating heat from an inside source. (M. 36.)

Paroxite AX Process. A method of treating alloy steels, e.g. corrosion-resisting steels, prior to cold deformation such as *drawing*, *extruding* or *pressing*. The treatment involves immersion of the steel part in the AX solution for a period of 15 to 30 minutes, followed by rinsing in cold water. The steel part is covered with a crystalline layer of complex salts which, it is claimed, causes lubricants to adhere to the surface of the steel and eliminates metal to metal contact between the parts to be drawn and the draw-plate.

Parsons Duncan Process. A method of casting steel ingots which comprises pouring the molten steel into a mould having its longitudinal dimensions greater than its vertical, thick refractory materials covering the sides of the mould. The mould is preheated to a high temperature and heat is continuously supplied to the upper surface of the molten metal after casting, so that the upper layer is the last to solidify. (P. 8.)

Parted Pattern. A *pattern* made in two or more parts. (A. 26.)

Partial Chamfer. A term applied where a portion only of an edge of a plate is bevelled across part of its thickness from one or both surfaces.

Partially Graphitized Cast Iron. A *blackheart malleable* casting that has only partly graphitized in annealing, giving a mixed black and white, sometimes termed *salt and pepper*, fracture. The metal is stronger and harder than true blackheart iron, but has considerably less ductility. This type of metal is sometimes purposely produced to meet certain applications and is then known as *pearlitic malleable iron*. (I. 14.)

Particle Adaptation. The term applied in powder metallurgy when powder particles change their shape and position, but do not shrink.

Particle Density. The mass of the actual volume of an individual particle. This value is applied in *powder metallurgy*.

Particle Size. In *powder metallurgy*, the controlling linear dimension of an individual particle as determined by analysis with screens or other suitable instruments.

Particle Size Distribution. The percentages expressed in terms of weight of the various sizes of particles in a powder sample when classified in terms of size ranges and measured in terms of screen mesh or microns.

Particle Transformation. The shrinkage of individual powder particles.

Parting. (*a*) The area of separation between the bottom face of the top part of the mould, and the top face of the bottom part. It is sometimes used to mean *parting powder*. (*b*) In the recovery of precious metals, the separation of silver and gold. (*c*) Removing a section of a piece by, for instance, a machine tool or abrasive wheel. For example, cutting down billets into *uses* for the production of drop forgings. (*d*) The selective corrosion of one or more components of a solid solution alloy.

Parting Compound. A material dusted or sprayed on *patterns* to prevent adherence of sand.

Parting Limit. The composition at which the chemical behaviour of an alloy abruptly changes.

Parting Line. (*a*) A line on a pattern or casting corresponding to the separation between the *cope* and *drag* portions of a sand mould. (*b*) In *drop forging* the intersection of the surface of the impression and the *parting plane*. (*c*) The *flash line* on a forging.

Parting Plane. The dividing plane between the two halves of a pair of *forging dies*.

Parting Powder. A powder made from chalk, bone meal or similar non-siliceous material, suitably water-proofed, which is applied to the pattern to ensure a clean strip from the moulding sand.

Parting Sand. Finely ground sand for dusting on surfaces that are to be separated in making a sand mould. It consists of a sharp sand that has been burnt dry and has no cohesiveness.

Pascoite. ($2CaO.3V_2O_5.11H_2O$.) A vanadium ore.

Pasopos Roll Pressure Tester. An instrument which measures the displacement of the lowest point of the lower roll body which occurs during rolling. A small roller, attached to one arm of a lever, rolls on the roll body, and the other end of the lever transmits its movements through a diaphragm capsule and tubing to the recording apparatus. Tests on the appliance show that the movements of the feeler roller are magnified ninety times by the recorder. (L. 56.)

Pass. (*a*) *Roll Pass.* In rolling, each passage of a piece of steel or other metal through a pair of rolls for the purpose of reducing the cross-section. A *live pass* is one in which this reduction is effected. In a *dead* or *dummy pass* there is no reduction of the cross-section as for example when the work is passed over the top roll of a *pull over mill* for repassing. In this case the term *gate* is sometimes used. (*b*) The open space between two grooved rolls in which the steel is rolled. (*c*) Drawing through a *die* for the purpose of reducing the cross-sectional area of the piece. (*d*) (*Run.*) In welding, the layer of metal deposited by each run of the filler metal along the seam.

Pass Reduction. (See REDUCTION.)

Passive-Active Cell. A cell, the *e.m.f.* of which is due to the potential difference between a metal in an active state and the same metal in a passive state.

Passive Electrode. (*Collecting Electrode.*) The earthed electrode of an electrical precipitation apparatus, from which the particles are deposited.

Passivating. Various oxidizing treatments have been suggested for increasing the passivity of stainless irons and steels, e.g. the use of chromate and of *anodic oxidation*. The best known use of this term, however, is in connection with the practice, chiefly in the U.S.A., of treating such steels in nitric acid with the primary object of removing surface impurities in order to eliminate the possibility of such particles acting as starting points of corrosive attack by *electrochemical action*.

Passivator. An *inhibitor* which appreciably changes the potential of a metal to a more cathodic value.

Passivity. The property exhibited by some metals whereby they become abnormally inactive towards certain chemical reagents. Thus, iron which is immersed in a copper sulphate solution will normally enter solution and precipitate copper on its surface, but in the passive state this tendency is less marked and its resistance to acid attack is very greatly increased. Passivity may be produced by immersing the metal in strong nitric acid, chromic acid, chromates, or other strongly oxidizing solutions which give rise to protective surface films. (See PASSIVATING).

Patent Office. 25 Southampton Buildings, Chancery Lane, London, W.C.2.

Patent Office Library. The Patent Office Library has a total stock of 360,000 volumes and is open to the public from 10 a.m. until 9 p.m. from Monday to Friday, and from 10 a.m. to 5 p.m. on Saturdays.

Patented Steel Wire. Carbon steel wire which has been hard drawn after *patenting*. *Best patented steel wire* is wire intended for the production of steel cables which has been drawn to a maximum stress of between 80 to 90 tons per sq. in. *Specially improved patent steel wire* is that quality which has been drawn to a maximum stress of between 90 and 100 tons per sq. in.

Patenting. Heating to a suitable temperature well above the transformation range, followed by cooling to a temperature below that range in air or in a bath of molten lead or salt maintained at a suitable temperature, to produce a structure which will facilitate subsequent cold working and give the desired mechanical properties in the finished state. The process is applied to medium- or high-carbon steel in wire making, between wire drawings.

Patents. *Letters patent* giving protection for *inventions* in the United Kingdom are granted for a period of 16 years. The period of protection for the provisional specification which is first filed is 12 months (stamp duty is 20/–). Sealing fee is 20/– to be paid before grant of patent. A fee of £4 paid when the complete specification is filed gives protection for 4 years and thereafter £5 for fifth year, £6 for sixth year and so on up to £16, which is sixteen years from the date upon which the complete specification was filed. Only under special circumstances, may this period be extended. Information may be obtained from any patent agent or from the Comptroller, at the *Patent*

Office. Copies of patent specifications may be obtained from the Sales Branch, at the same address.

Pathfinder Back-Pull Wire-Drawing Machine. A five-block wire-drawing machine. Each block is driven by its own D.C. motor. The armatures are arranged in series, but the fields are in parallel so that, by means of grid control on the rectifier, the power developed by each motor can be adjusted within certain limits. The machine is designed to draw high carbon steel wire at speeds up to 1600 ft. per min. with a total power consumption of 160 brake h.p. A back-pull is exerted. (E. 55.)

Patina. The green colouration seen on old copper roofs. It consists chiefly of basic copper sulphate with a little basic copper carbonate.

Patronite. A most important vanadium bearing mineral, named after the discoverer of the rich vanadium deposit lying at an altitude of 16,000 ft. in the Peruvian Andes. It consists of vanadium sulphide mixed with metallic sulphides and may contain about 20% vanadium.

Pattern. (*a*) A model, in wood or other suitable material, of the required *casting*. The sand of the mould is rammed round the pattern which is then withdrawn leaving a cavity of its exact size and shape to be filled with molten metal. If holes or interior passages are required in the casting it is provided with *core prints*. (*b*) A full-scale reproduction of a part used as a guide in cutting. (*c*) A regular array of characters such as an X-ray diffraction pattern.

Pattern Board. A board, reinforced with *cleats*, having a true surface upon which a *pattern* is laid for the ramming of the *drag*. (A. 26.)

Pattern Checking. Verifying the dimensions of the *pattern* with those of the drawing. (A. 26.)

Pattern Coating. Coating material applied to wooden *patterns* to protect them against moisture and abrasion by the *moulding sand*. (A. 26.)

Pattern Die. A body composed of two or more mating parts, containing one or more negative impressions of the master pattern and used for production of expendable patterns.

Pattern Draft. The taper on vertical elements in a *pattern* which allows easy withdrawal of the pattern from the sand *mould*. (A. 26.)

Pattern Effect. (See INGOTISM.)

Pattern, Grand Master. A pattern constructed with triple shrinkage allowance from which metal master patterns are made.

Pattern Injection. The process of filling the pattern die with expendable material, usually in the liquid or plastic state.

Pattern Layout. A full-sized drawing of a pattern showing its arrangement and structural features. (A. 26.)

Pattern Letters. Identifying symbols affixed to a *pattern* as a means of recording the pattern and identifying the *casting*.

Pattern Members. Component parts of a *pattern*. (A. 26.)

Pattern Plates. Straight flat metal or other plates upon which *patterns* are mounted. (A. 26.)

Patternmaker's Shrinkage. Shrinkage allowance made on all *patterns* to compensate for the change in dimensions as the casting cools in the mould from the freezing temperature of the metal to room temperature. The pattern is made larger by the amount of shrinkage characteristic of the particular metal in the casting and the amount of hindered contraction to be encountered. Rules or scales are available for use. (See MOULDER'S RULE.) (A. 26.)

Patternmaking. A highly skilled craft of modelling the desired casting in wood, metal or other materials.

Pb. Chemical symbol for *lead*, from the Latin *plumbum*.

P.C.E. (See PYROMETRIC CONE EQUIVALENT.)

Pd. Chemical symbol for *palladium*.

P.D. *Potential difference*.

Peabody Hardness Tester. A pocket-sized metal hardness tester of the rebound type, weighing only 7 oz. which makes possible testing of internal mould and die sections with an area as small as 1 sq. in. Direct readings are obtained on any of the Rockwell or Brinell scales without use of conversion charts.

Pean. (See PEEN.)

Pearlite. The *lamellar* conglomerate of *ferrite* and *cementite* which constitutes the eutectoid in the *iron-iron-carbide* equilibrium system. It results from the transformation of austenite at or below Ar_1, and is so called from the mother-of-pearl lustre given by an etched surface when viewed under the microscope. This pearly appearance is due to the fine and regular alternation of the two constituents and the fact that cementite, being harder than pearlite, is left in relief after polishing. The lamellar arrangement of ferrite and cementite produces a very tough structure and is responsible for the mechanical properties of the unhardened steels. Pearlite is present in small quantities in low carbon steels and increases in quantity as the carbon increases until in a plain carbon steel containing about

0·83% of carbon the structure consists entirely of pearlite. (See Plates VII, VIII (a), (b), (c) and IX (a).)

Pearlitic Malleable Iron. (*Bull's Eye Malleable.*) Malleable iron in which the graphitizing reaction has been arrested in the later stages, thus leaving up to about 0·9% of combined carbon, i.e. *pearlite*, in the matrix. The typical structure in which nodules of black *temper carbon* are bordered by ferrite, against a matrix of pearlite has given rise to the name of bull's eye malleable. (See also PARTIALLY GRAPHITIZED CAST IRON.)

Pearlitic Stainless Steels. These contain from 12% to 16% chromium with about 0·30% carbon. Such steels are capable of being hardened, and they are used for cutlery and engineering purposes. (See also STAINLESS STEELS.)

Pebble Heater. A type of apparatus which is capable of heating gases above the operating temperatures permissible in metallic heat interchangers. The principle involved consists of heating refractory pellets by means of high-temperature gases and then passing a gas to be heated through a permeable bed of the heated pellets. (N. 20a.)

Pebbling. (See ORANGE PEEL EFFECT.)

P.E.C. Abbreviation for *photo electric cell*.

Pechiney Cartoux Furnace. A triphase indirect arc furnace developed in France for foundry use.

Peddinghaus Process. This process involves the rapid heating of the surface of the steel to the hardening temperature and quenching it before the heat has penetrated below the depth of the hard case required. The process is automatic and the heat is derived from an oxy-town gas flame. The heating of the steel is so rapid that the use of an ordinary pyrometer is impracticable. Peddinghaus have perfected an automatic temperature control known as the *milliscope* which is capable of responding to extremely rapid changes of temperature when used in conjunction with the flame heating machine. The milliscope is set to the temperature required, and as soon as this is reached a direct current is generated which controls the speed of the burner travel of the flame, and in other cases is used to transfer the component being treated from the heating to the quenching position. (T. 41.)

Peel. (*a*) A long iron rod some 10 ft. in length, one end of which is shaped to form a handle, and the other, forged into a flat blade. Such tools were used for the charging and distribution of pig iron in the hand charging of hearth furnaces. (*b*) (See PEELING).

Peel Test. A test for the determination of the strength of *Redux* bonded joints. The test consists of pulling against an autographically recording loading device in which the peel specimen is clamped to a circular drum, the free end being held in a suitable clamp. The drum is then pulled hydraulically, which causes the specimen to rotate and peel the two component strips apart. (P. 4.)

Peeling. (*a*) (*Peeling Disease.*) (*Peel.*) The presence, in *whiteheart malleable iron* of an easily detached surface layer consisting of partially oxidized metal in conjunction with a brittle iron sulphide rich film at the peel/metal surface. The existence of *peel* can sometimes be recognized by the presence of lentil-like blisters on the surface of the casting which, on breaking away from the surface, leave fairly smooth cavities of a grey oxidized appearance. In some castings, however, the appearance is normal and the defect is found only after mechanical deformation. The primary cause of peeling is the use of high sulphur ores for *malleablizing*. (H. 83.) (*b*) The dropping away of sand from the *casting*. (*c*) The separation of a deposit from the underlying surface.

Peen. (*Pane*, *Pean*, or *Pene.*) That end of the hammer head which is opposite to the hammering face. It is made to various shapes according to the purpose for which it is intended, e.g. *riveting*. (See PEENING.)

Peening. The mechanical working of metals by means of hammer blows. (See SHOT PEENING.)

Peephole. (*Eye*, *Eyesight.*) A small glass-covered opening so placed that it permits inspection of that part of the interior of a blast furnace which is directly in front of the *tuyeres*.

Peg Gate. A round gate leading from a *pouring basin* in the *cope* to a basin in the *drag* from which *sprues* lead to the *mould*.

Peg Rammer. (See RAMMER.)

Pehrson-Prentice Process. A method of producing steel direct from ore. The crushed ore or iron sand, after removal of gangue by magnetic concentration, is mixed with an adequate quantity of carbon to effect reduction. After drying and preheating, the charge enters the end of the centre portion of the furnace, where it is quickly reduced into a metallic state at a temperature of 950° to 1000° C. The grain iron is then directly melted and suitable additions made according to the grade of steel required. (S. 79.)

P.E.I. Porcelain Enamel Institute (U.S.A.).

Pellet Test. A rapid method of identifying alloy steels, used in conjunction with the *spark test*. The burnt particles from the spark test are collected on a sheet of paper and examined at 25 to 30 diameters; when chromium is present the pellets are spherical with a matt grey surface; molybdenum causes the pellets to become hemispherical, and hollow if the carbon is high; vanadium causes the pellets to erupt like a miniature volcano and it produces a black surface on them. (L. 18.)

Pelletizing. Pellets are formed from fine-grained ore by tumbling in an open-ended drum. A definite moisture content is maintained and the temperature within the drum is kept at 60° to 70° C. The pellets are then fired at temperatures between 1000° and 1070° C. according to the nature of the original ore. (S. 41.)

Pellin Hardness Tester. A dynamic hardness testing instrument of French manufacture which employs a 2·5 mm. ball indenter of variable weight. It is released magnetically from a variable height.

Peltier Effect. The phenomenon whereby heat is liberated or absorbed at a junction where an electric current passes from one metal to another.

Pelton Water Wheel. A wheel having a series of suitably shaped buckets attached to its periphery, these buckets being so arranged that they are struck by a jet of water discharged at high velocity.

Pencil Core. A *core* projecting to the centre of a *blind riser* to admit atmospheric pressure to force out feed metal.

Pencil Gating. Gating directly into the *mould* cavity through the *cope* by means of one or more small vertical gates connecting the pouring basin and mould cavity.

Pendoscope. A small portable hardness testing instrument of German manufacture.

Pendulum Hammer. A machine for dynamic hardness tests in which a steel ball is mounted on a heavy pendulum and driven into the test piece by the fall of the pendulum, and the angle of rebound is noted. The general arrangement is much like that of the Izod notched bar impact tester, and the machine can be used for both dynamic hardness and notched bar tests. (W. 8.)

Pene. (See Peen.)

Penetral Process. A method of improving the resistance of mild steel to high temperature oxidation and dry sulphurous gases. Up to $\frac{1}{16}$ in. is impregnated to form a complex aluminium-iron alloy containing chromium and silicon. Nickel-chromium steels may also be protected in the same way. (B. 94.)

Penetrameters. A series of gauges of varying thickness used in radiographic inspection for determining the resolution or sensitivity of the process. Such devices bear markings which are so designed that they are visible under appropriate conditions on the radiograph. In British practice (B.S. 1500) for the radiographic examination of fusion welded pressure vessels the penetrameter is of the *step-wedge* type in the form of a steel strip $\frac{1}{2}$ in. wide made in a series of steps each $\frac{1}{2}$ in. long. For thicknesses of plate up to $1\frac{1}{2}$ in., the thicknesses of the steps are 5-, 10-, 20-, 30- and 40-thousandths of an inch respectively. Each step is perforated with holes $\frac{1}{40}$ in. in diameter arranged in the form of a numeral relating to the thickness of the step. In Canadian practice, the number 1 penetrameter is intended for metal thicknesses up to 2 in. with five penetrameter steps from 0·005 to 0·040 in. The number 2 penetrameter is intended for metal thicknesses from 2 to $4\frac{1}{2}$ in. with six penetrameter steps from 0·040 to 0·090 in. German standard No. DIN 54110 provides for the use of a *wire penetrameter* to measure sensitivity. This consists of seven metal wires (either steel, copper or aluminium) of graduated thicknesses embedded in a case of thin rubber. Four different penetrameters in each metal are required to cover the range of specimen thicknesses up to $3\frac{1}{2}$ in., the wires varying in diameter from 0·1 to 4·0 mm. The penetrameter in use is distinguished visually by the colour of the rubber and on the radiograph by a lead number embedded in the rubber. The most suitable penetrameter is selected by trial and laid on the tube side of the specimen, the diameter of the thinnest wire just visible on the film, expressed as a percentage of the specimen thickness, giving the *wire sensitivity*. This shows the radiographic quality of the image, but does not indicate the defect sensitivity, i.e. the smallest defect which can be detected. For this, a device called the *bacillae test* is used, which involves counting the images of a number of small pieces of wire of such diameter that they come within the limit of visibility and invisibility on the radiograph. (V. 7.)

Penetrascope. A portable diamond pyramid hardness tester, in which the indenter is operated by the hydraulic

thrust unit, no external source of power being required. The load applied can be varied by turning a knurled wheel and is indicated on a dial. After the indentation has been made, the width across the diagonals is measured with the aid of the microscope and a micrometer counter. The resulting reading in decimals of a millimetre is converted to the ***diamond pyramid hardness number*** by reference to the tables in British Standard No. 427. (E. 57.)

Penetron. A gamma-ray instrument used to facilitate the detection of internal corrosion. It operates by measuring secondary radiation from gamma rays that are directed into the metal being tested. An accuracy of $\pm 5\%$ over its range of measurement, between 0 and 0·75 in. thickness, is obtainable. (K. 13.)

Penetration. (*Root Penetration.*) The depth of *weld metal* in a *butt weld.* (Cf. IMPERFECT ROOT PENETRATION.)

Penetration-Fracture Test. (*Shepherd P.F. Test.*) A hardenability test which consists in hardening in brine four samples machined to ¾ in. round by 3 in. long. One round each is treated from 790°, 815°, 845° and 870° C. Each round is notched in the middle and fractured by impact. One half of each is examined for grain size of the case by comparison with a standard set of *Shepherd fractures.* Penetration tests are made on the other half of each by grinding and polishing, followed by etching 3 minutes in 1:1 hydrochloric acid solution at 180°. The hardness penetration is measured in 64ths of an inch. (S. 56.)

Penetrometer. (See HOGGATT'S PENETROMETER.)

Pennsylvania State College, Dept. of Mineral Technology, State College, Pennsylvania, U.S.A. (Dr. Maxwell Gensamer, Prof. of Metallurgy.)

Pennyweight. 24 grains, $\frac{1}{20}$ troy oz.

Pensky Martens Flash Tester. Apparatus designed for the determination of the *closed flash point* of oil. The oil sample is poured into a cup which is closed by a tightly fitting cover provided with a revolving perforated slide operated by a spring lever. Heat is applied by means of a burner below the cup, the oil being continually stirred by means of a special device. As the temperature is raised, the lever operating the slide is turned and openings in the slide are made to coincide with the corresponding openings in the lid and a small burning gas jet is automatically dipped into the aperture into the air space above the oil. This is repeated at intervals of 2° F. until the mixture of air and vapour above the oil becomes inflammable and flashes when contacted by the flame, the temperature of this flash point being read off on the thermometer provided.

Penstock. (See TUYERE STOCK.)

Pentlandite. A sulphide of iron and nickel usually corresponding to the formula (Fe,Ni)S. It is the principal ore of nickel.

Pentrating Process. A salt-mixture controlled oxidation process applied to ferrous metals. It is claimed that the resultant lustrous black finish adds to the durability of the metal surface and has marked anti-friction and anti-rust qualities. (I. 32.)

Per-. Prefix denoting a higher oxygen content than the normal acid or salt, e.g. permanganate.

P.E.R.A. Production Engineering Research Association.

Percentage Elongation. The increase in gauge length of a tensile test piece, expressed as a percentage of the original gauge length. In reporting elongation values on non-standard test pieces, the ratio of gauge length to the square root of the cross-sectional area should also be quoted.

Percussion Welding. A *resistance welding* process in which fusion is produced simultaneously over the entire area of abutting surface by the heat obtained from an arc produced by a rapid discharge of stored electrical energy, with high pressure percussively applied, usually a hammer-like blow, during or immediately after the electrical discharge.

Percy, John. (1817–88.) Lecturer and metallurgist at the Royal School of Mines and to the Royal Artillery. Author of *Iron and Steel,* published in 1861.

Perflow Process. A nickel-plating process which possesses the property of filling-in scratch marks. In most cases some of the polishing steps in the preparation of the base metal prior to plating can be eliminated.

Peri-. A prefix denoting around or about.

Periclase. Native magnesia, MgO. (See also MAGNESITE.)

Periodic Annealing Furnace. A furnace in which the charge passes through a complete cycle of preheating, soaking and cooling.

Periodic Classification. (See PERIODIC TABLE.)

Periodic Law. The properties of the elements are a periodic function of their atomic weights. This is most clearly demonstrated when the elements are arranged in a *Periodic Table.*

Periodic Reverse-Current Process. (*Jernstedt's PR Process.*) A process of

electroplating, by which the plated deposit shows superior physical properties and freedom from flaws such as porosity, and in which the current is reversed at short intervals, thereby removing unsound metal deposited in the previous plating period and building up many microscopically thin layers of metal to form a deposit of high density and homogeneity. The surface of the deposit is smoothed with each succeeding increment, and heavy thicknesses of plate, for example, ¼ in. can be produced without surface flaws. (B. 82.)

Periodic Table. (*Periodic Classification.*) An arrangement of chemical elements in ascending order of atomic numbers, in which elements of similar chemical properties appear periodically and fall into nine definite groups. The classification was carried out by D. I. Mendeleeff and L. Meyer, about 1869. (Cf. LAW OF OCTAVES.)

Peripheral Speed. The speed of the outside surface of a disc, wheel, roll, etc., usually stated in ft. per minute or ft. per second.

Peritectic Reaction. (*Peritectic Transformation.*) An isothermal reversible reaction in binary alloy systems, in which a solid and a liquid phase react during cooling, to form a second solid phase, e.g. when *delta iron* plus liquid transforms on cooling to form *gamma iron*.

Peritectic Transformation. (See PERITECTIC REACTION.)

Peritectoid Reaction. An isothermal reversible reaction in binary alloy systems, in which two solid phases react during cooling to form a new solid phase. (The inverse of a *eutectoid*, a peritectoid, is sometimes called a *metatectic*.) (A. 27.)

Perlit Iron. A high duty pearlitic cast iron produced by the *Lanz Perlit Process*.

Perliton. A liquid carburizer which is used in ordinary salt bath furnaces, for case hardening processes. (M. 23.)

Perm-Cote. A phosphate coating material recommended as a replacement for cadmium or zinc in many rust-proofing applications. When immersed in a solution of the material, iron and steel surfaces are chemically converted into a dark grey, uniform, dense, non-metallic phosphate coating. After rinsing, the highly absorbent coating is impregnated with a rust proofing oil known as *Perm-Oil*, which gives the product a permanent corrosion-proof layer that is dry to the touch. (I. 11.)

Perm-Oil. (See PERM-COTE.)

Permaclad. Mild steel sheet coated with 18/8 type austenitic corrosion resistant steel by diffusion welding.

Permadine. A rust-preventive zinc-iron phosphate coating for iron and steel.

Permanent Deformation. (See PERMANENT SET.)

Permanent Extension. (See PERMANENT SET.)

Permanent Hardness. The hardness which remains in water after prolonged boiling, due to the presence of calcium and magnesium chlorides or sulphates.

Permanent Linear Change on Reheating. (See AFTER CONTRACTION or AFTER EXPANSION.)

Permanent Load. The fixed or *dead load* on a structure which includes the weight of the structure itself together with any static load carried by it, as distinct from any *live load*, i.e. moving load, carried by it.

Permanent Magnets. (See MAGNET.)

Permanent Mould Castings. A term used in the U.S.A. for *gravity die castings*.

Permanent Mould Die Casting. (See DIE CASTING.)

Permanent Moulds. (See CHILL MOULDS.)

Permanent Record of Magnetic Patterns. (See FERROGRAPH.)

Permanent Records of Structures. (See MACROPRINTS.)

Permanent Set. (*Permanent Deformation, Permanent Extension.*) (*a*) An extension remaining after the load has been removed from a test piece, when the elastic limit has been exceeded. (See ELASTIC LIMIT.) (*b*) Permanent deflection of any structure after being subjected to a full load.

Permeability. (*a*) A measure of the ease with which the magnetic lines of force can pass through a substance for a given magnetizing force. Quantitatively, it is expressed as the ratio between the magnetic flux density (B) produced and the magnetizing force (H) producing it; the term used to designate this ratio is the Greek letter μ (mu). Thus, permeability $\mu = \frac{B}{H}$. (*b*) In sand, the rate of flow of air through a standard test piece prepared in a standard manner, expressed as the volume of air in ml. which passes per minute under a pressure of 1 cm. water gauge through a test piece 1 cm. long and 1 sq. cm. cross-section.

Permeability, Incremental. The ratio of the cyclic change in magnetic induction to the corresponding cyclic change in magnetizing force when the mean induction differs from zero. (A. 28.)

Permeance, p. The ratio of the *magnetic flux* through any cross-section of a tubular portion of a magnetic circuit bounded by lines of force and by two equipotential surfaces to the magnetic potential difference between the surfaces taken within the portion under consideration. (A. 28.)

Permutite. A synthetic *zeolite* produced by igniting together clay, sand, and an alkaline carbonate. It is used for the removal of the salts of calcium, magnesium, sodium and potassium from water, i.e. as a water softener.

Pernot Furnace. An open hearth furnace, of about 1877, in which the hearth rested on a trolley which could be moved to facilitate repairs and could also be made to rotate. (M. 3.)

Peroxide. (*a*) An oxide which yields hydrogen peroxide when treated with acid. (*b*) A compound of an element with oxygen in which the element exhibits a higher valency.

Perrin Process. There are various modifications of this process. (*a*) Molten pig iron containing about 0·30% of phosphorus is blown in an acid-lined Bessemer converter, and the resultant blown metal is rapidly dephosphorized by pouring it from a sufficient height into a basic oxidizing slag contained in the casting ladle. Alloys are then added in a red-hot condition to the dephosphorized blown metal and the finished steel is cast into ingots. By this method low-carbon steel ingots can be manufactured direct from the acid Bessemer converter when using a pig iron that is too high in phosphorus for the normal acid Bessemer process. The slag employed for the dephosphorization of the Bessemer blown metal may either be a synthetic slag, or a basic open-hearth furnace slag sufficiently low in acids and high in iron oxide, such as may be obtained in the making of a low-carbon *rimming steel* heat, but dephosphorization is not so intensive with a basic open-hearth slag as with the synthetic slag, owing to the much lower acid content of the latter. Also the intensity of the dephosphorization can be regulated to a certain extent by the percentage of dephosphorizing slag employed. For the production of acid open-hearth steel from the same phosphorus-bearing pig iron, a duplex process is employed in which the dephosphorized partly-blown metal containing a sufficient percentage of carbon is charged into an acid open-hearth furnace and the heat finished under an acid slag to the required chemical composition. (Y. 1.) (*b*) Violent intermixing of steel and a predetermined slag for sulphur removal carried out to the point of emulsification. A siliceous slag, very low in iron was initially used. An aluminous slag has since been adopted. One-half to two-thirds reduction in sulphur is claimed. (S.146a.) (*c*) The process has been modified for the production of low carbon ferro-chrome. A typical plant consists of four electric furnaces, two of the submerged-arc type, which are charged with lumpy chrome ore, flint and coke, thereby producing a high-silicon ferro-chrome substantially free from carbon. The second pair of furnaces are fed with washed chrome ore concentrates and lime, producing a synthetic slag, which is tapped at regular intervals into a large ladle. To this slag is added a secondary ferro-silicon chrome in sufficient quantity to reduce about half of the Cr_2O_3 thus producing a low-silicon and low-carbon ferro-chrome. The remaining slag is decanted into another ladle and the metallic low-carbon ferro-chrome cast into ingots. As the decantation is taking place, molten ferro-silicon chrome produced in the submerged arc furnace is poured into the same ladle, thus reducing the Cr_2O_3 remaining in the partially exhausted slag and producing the secondary ferro-silicon chrome which is used in the first stage of the reduction. (I. 61.)

Petrography. The systematic study of rocks based on their mineralogical and textural characteristics as observed on field specimens and on microscopic sections. (Cf. PETROLOGY.)

Petrology. The study of the origin and formation of rocks.

P.F. Test. (See PENETRATION FRACTURE TEST.)

Pfender Extensometer. A portable instrument for determining changes of length of any number of components. The selected gauge length, which may be from 20 to 500 mm. is marked by centre punches, and the punch marks are enlarged so that hardened steel balls, $\frac{1}{16}$ in. diam. can be fitted into the holes. The extensometer feet are counterbored to fit these balls. One foot is integral with the frame of the instrument, the other actuates a dial gauge through a 1:5 ratio bell crank. To use the instrument, a trigger is pressed which uncouples the dial gauge from the gauge feet; a very slight pressure then suffices for the feet to centre on the ball marking the gauge length. The trigger is then released. This firstly clamps the bell-crank lever in place, and then slowly lowers the spindle of the dial gauge on to the bell

crank. The bell crank remains clamped until the trigger is again pressed, so that it is possible to remove the instrument, which can easily be operated with one hand, and to defer reading the dial gauge until some convenient opportunity. (E. 15.)

***p*H Value.** The logarithm to the base 10 of the reciprocal of the concentration of the hydrogen ions in gram molecules per litre in an aqueous solution. Thus, water has a *p*H value of 7; acidic solutions are less than 7, and basic solutions are higher than 7. It affords a method of expressing small differences in the acidity or alkalinity of nearly neutral solutions.

Phase. A physically and chemically homogeneous portion of a system. Solid phases in an alloy may be elemental metals, solid solutions or compounds.

Phase-Contrast Incident-Light Microscope. An instrument which gives images similar to those obtained from plastic film replicas without their high resolution, but with the advantages of direct vision and unrestricted scanning. It provides micrographs dependent upon phase changes involved in the reflection of light from various materials, in addition to the variations in surface level in the specimens. This microscope has a high resolving power. (C. 58.)

Phase Diagram. (*Constitutional* or *Equilibrium Diagram.*) A graphical representation of the equilibrium temperatures and composition limits of *phase fields* and phase reactions in an alloy system. It is constructed from thermal and other data showing the limits of temperature and composition within which the different constituents and phases of the alloy system in question are stable. In a binary system, the temperature is usually the *ordinate* and the composition the *abscissa*, and from this the changes of structure and the composition of the constituents in equilibrium at any specified temperature can be determined. Ternary and more complex systems require several two-dimensional diagrams to show completely the temperature-composition variable. In metal systems, the pressure is usually taken as constant, although it may be taken as an additional variable.

Phase Field. The area in a constitutional or equilibrium diagram occupied by a single phase or a mixture of two phases. A field in which two phases are present usually separates two single-phase fields occupied by each of these separate phases, respectively.

Phase Rule. A relationship between the number of phases, the components and the degrees of freedom of a system was developed in the nineteenth century by *Gibbs*. This rule, based on thermodynamic concepts, and applied to metals in equilibrium may be stated mathematically as follows:

$$F = C + 2 - P$$

where F = degrees of freedom
C = number of components
P = number of phases.

The degrees of freedom are the number of independent variables (either temperature or concentration of the phases) which may be altered without causing the disappearance of any phase, or the formation of a new phase. Components in alloy systems are metals or their compounds, and, for a given system, there should be chosen as components the smallest number of independently variable constituents by means of which the composition of each phase can be expressed. Phases are physically distinct matter, such as the physical states, liquid or solid, with the latter having several possible forms, namely, pure metals, compounds and solid solutions. The phase rule is a useful guide in the construction of alloy diagrams. (G. 27.)

Phenolic Sand Moulding Process. Essentially the method consists of producing a comparatively thin shell-like metal-casting mould by applying a mixture of sand and a phenolic binder to a hot metal pattern and curing the layer of material. (See CRONING PROCESS.) (M. 149.)

Phlogopite. A mineral, magnesium mica, used as an insulator.

Phosphate Coatings. (*Phosphatizing.*) Phosphate coatings, under various proprietary names, have several functions. (1) To facilitate the bonding of paint and other organic finishes to steel and iron. (2) To reduce *wear* and *galling* and to facilitate cold working operations. (3) To provide rust resistance. For the latter purpose the iron or steel parts are immersed in a heated solution of manganese iron phosphate, or zinc iron phosphate, which provides a phosphate coating integral with the basis metal. The protective effect of the coating so formed may be enhanced by re-dipping in a dilute solution of chromic acid and sealing with oil, the oil absorptive property of these coatings rendering them capable of retaining appreciable quantities of the sealing agent.

Phosphoferrite. (See FERROFERRITE.)

Phosphatizing. (See PHOSPHATE COATING.)

Phosphide. Phosphorus unites directly with many metals forming compounds known as phosphides, e.g. iron phos-

phide, Fe_3P, which are brittle solids. The corresponding compound with hydrogen, PH_3, hydrogen phosphide, phosphine or phosphoretted hydrogen, is a gas.

Phosphide Streak. An elongated area of segregated phosphides which is revealed on etching.

Phosphor Bronze. An alloy of 70% to 97% copper, 3% to 13% tin, 0% to 16% lead and 0·1% to 1·0% phosphorus, and sometimes a little zinc. The alloys for casting usually contain 85% to 92% copper, 7% to 13% tin, 0·3% to 1·0% phosphorus, and traces of lead and zinc. For malleable phosphor bronze the alloys consist of 94% to 97% copper, 3% to 5% tin and 0·1% to 0·35% phosphorus. Phosphorus is added to bronze as a deoxidizer, and small further additions increase the strength. Bearing bronzes contain about 10% tin and 0·5% to 1·0% phosphorus. Phosphor bronze is generally used for its wear and corrosion resistance properties.

Phosphorus. (*P.*) *Atomic weight* 30·975. *Melting point* 44·1. A non-metal having five *allotropes*. In steel it is generally regarded as an undesirable impurity and exists as an iron phosphide, Fe_3P, dissolved in the ferrite and segregating to a considerable extent; on rolling, the high phosphorus segregations are elongated into bands forming *ghosts*. Phosphorus raises the tensile strength (by about 0·4 tons for each 0·01% of the element present) and also increases the elastic limit, but it lowers the ductility, inducing brittleness. On this account most British Specifications limit the phosphorus to less than 0·05% and in the case of tool steels to 0·03%. Phosphorus improves the resistance of steel to atmospheric corrosion, particularly in the presence of copper, and in American practice, it has been enlisted as an alloying element as it is contended that so long as the sum of the carbon and phosphorus does not rise above 0·30% the impact resistance is not seriously reduced. Hence, the permissible phosphorus content is strictly limited by the carbon content, and the use of phosphorus is usually confined to structural steels containing less than 0·15% carbon.

Phosphorus Printing. A method of revealing and recording the phosphorus distribution on a prepared surface of steel. Photographic or filter paper is first soaked in an aqueous solution containing 35% of nitric acid and 5% ammonium molybdate. The paper is then drained and laid on the steel surface for about 5 minutes. It is then removed and developed in an aqueous solution of 35% hydrochloric acid to which is added a little alum and 5 ml. of a saturated stannous chloride solution. The location and intensity of the blue areas formed on the print indicate the distribution and amount of phosphorus present.

Phosphorus Sweat. The phosphide eutectic extruded by some high phosphorus iron castings.

Phosphoroscope. An instrument for measuring the duration of *phosphorescence* in different substances.

Photelometer. Apparatus for the determination of particle size which uses a turbidimetric-sedimentation method based upon the measurement of transmission of a parallel beam of light through a suspension of powder while the powder is allowed to settle. The light is transmitted through a narrow slit at a fixed reference level below the surface of a suspension, the instrument having been calibrated initially with the clear liquid medium in the light path. Particle-size distribution and surface area may be calculated from the fundamental relationship between light transmission and surface area. The apparatus utilizes small samples (0·05 to 0·1 gram depending upon coarseness of the powder.)

Photocell Pyrometer. (See BROWN-FIRTH PHOTOELECTRIC PYROMETER.)

Photo Defectoscope. An instrument for the detection of defects in metals by means of photoelectric measurements. (S. 76.)

Photoelastic Dynamometer. An apparatus for the measurement of rapidly varying forces. It consists of a glass slab, upon which the forces act, placed between two polarizers; the intensity of the light transmitted is a measure of the force. It is indicated by a vacuum photocell in conjunction with an A.C. amplifier and a cathode-ray oscillograph. The arrangement has been used for recording the variation of pressure over the area of contact in rolling mill research. (O. 17.)

Photoelastic Stress. (See PHOTOELASTICITY.)

Photoelasticity. (*Photoelastic Stress.*) A technique for the investigation of stresses in engineering structures. The general method consists in examining the patterns produced by passing polarized light through a stressed model of the structure, made in a plastic material having suitable optical properties. It is then possible to calculate the magnitude and directions of stresses at all points in the model. New plastics have recently greatly extended the

scope and usefulness of the method. (See also FROZEN STRESS.) (J. 14.)

Photoelectric Cell. A device by which light can be detected and measured electrically. There are three types: (*a*) In the emission type, light falling on a metal surface (*cathode*) in an evacuated glass bulb releases electrons and a positively charged electrode (*anode*) nearby, collects them, forming an electric current. The wave-length of the light must be shorter than a characteristic value for each metal, *caesium* having a high value which makes red light detectable. (*b*) The conductivity type depends on the decrease in ohmic resistance of a thin film of poorly conducting material when exposed to light. *Selenium* was used, but recently lead sulphide has been found to respond well to the infra-red or heat radiation of much longer wave-length than visible light, which is emitted by hot surfaces between 150° and 600° C. (*c*) In the rectifier, voltaic, or barrier layer type, a thin film of a semi-conductor, usually selenium or cuprous oxide, in close contact with a metal plate, is exposed to light. More electrons pass from the semi-conductor to the metal than vice versa, so that an electromotive force is produced which will drive a current through a galvanometer. All may be used with amplifiers and relays for detection, measurement, control of radiation or values such as temperature with which radiation may be connected. (See BROWN-FIRTH PHOTOELECTRIC PYROMETER.)

Photoelectric Effect. Any change in the electrical properties of a body produced by the action of light, e.g. the generation of an *e.m.f.*, a change of resistance or a loss of charge. (B. 105.)

Photoelectric Extensometer. A type of *extensometer*, 40 mm. long and weighing about 15 gm. The gauge points are 2 mm. apart and the extension is magnified mechanically about 50 times by levers which cause a slit to vary its width. A ray of light from a lamp within the extensometer passing through the slit falls on a small plane *photoelectric cell* at the end of the instrument, and the current produced is magnified until a total extensometer magnification over 30,000 times is obtained. (L. 22.)

Photoelectric Pyrometer. A *photoelectric cell* of the emission type used to measure high temperatures, e.g. radiation from hot steel. It has an interrupter in the optical path to avoid the difficulties of amplifying direct current. Negative feedback in the amplifier gives constant sensitivity, and the output may be shown on an indicator or recorder in addition to operating a relay giving automatic control. The instrument has a rapid response, high sensitivity, constancy, and suitability for recording and control. (See also BROWN-FIRTH PHOTOELECTRIC PYROMETER.) (R. 31.)

Photographic Pyrometer. An instrument which indicates apparent surface temperatures by photographing hot surfaces and correlating the variable density of the photographic negative with the apparent surface temperature. The need for critically controlled photographic and development technique is eliminated by incorporating into every photograph the images of standard targets whose apparent surface temperatures are independently determined with an optical pyrometer. (M. 68.)

Photographic Thermometry. (See PHOTOGRAPHIC PYROMETER.)

Photogrid Process. A process used in studying metal deformation, e.g. in cold pressing. A rectangular or polar grid is recorded photographically on the surface of the specimen, and the distortion of the grid, arising from working the metal, is used to determine the local deformations. (B. 91.)

Photogoniometer. An X-ray *goniometer* with photographic registration.

Photomacrograph. (See MACROGRAPH.)

Photometer. An instrument for the measurement of light intensity or the degree of light absorption.

Photomicrograph. (See MICROGRAPH.)

Photosedimentometer. An instrument for the routine sub-sieve analysis of metal and other powders. Collimated and filtered light from a single source is passed to two photo-cells, the one beam of light being intercepted by a liquid suspension of the powder specimen. The specific surface of the powder is given by the automatic potentiometer recordings of voltage ratio changes between the two photo cells. (M. 108.)

Physical Change. The alteration of the physical properties of a substance without any accompanying change in its chemical composition.

Physical Chemistry. The study of the inter-relation of chemical and energy changes.

Physical Constants. The values of characteristics of chemical substances such as the *atomic weight, melting point* and *coefficient of expansion*.

Physical Metallurgy. The science concerned with the physical and mechanical characteristics of metals and alloys.

Physical Properties. Those properties of a body which do not involve any change in its chemical composition,

e.g. density, electrical conductivity, magnetic properties, and coefficient of thermal expansion.

Physical Testing. Testing methods by which *physical properties* are determined. This term is also used inadvisedly to mean the determination of the mechanical properties. (A. 27.)

Physics. The science concerned with the properties of matter and energy.

Pi. (See π.)

Piano Wire. (*Music Wire.*) Wire made from the best-quality plain carbon steel, with a carbon content of about 0·80% to 0·95%. It is usually drawn to a tensile stress of more than 120 tons per sq. in. The term *music wire* also includes wire intended for mandolins.

Pick Method. A method of ore dressing developed at Montanische Hochschule at Leoben. (B. 53.)

Picker. A pointed steel rod used, in the absence of a *rapping plate*, to assist in the withdrawal of wooden patterns from the half mould.

Picker-Polaroid Process. A process developed primarily for medical radiography. In addition to the conventional X-ray apparatus, it employs a composite pack containing a negative, a pod filled with viscous developing jelly, an intensifying screen, and a positive image receiving sheet. After exposure, the pack is passed through rollers which break the pad and spread the developing jelly. The dry positive print is ready in 1 min. (R. 21.)

Pickle Lag. A phenomenon in tinplate steels which is associated with poor internal corrosion resistance of tin cans. It is traced to the occurrence of grain boundary oxides in the surface layers of the steel. The conventional method for checking for pickle lag involves determining the rate of weight loss or hydrogen evolution of the untinned or detinned steel in 6N hydrochloric acid at 90° C. In untinned black plate the presence of grain boundary oxides may be directly checked with the aid of a metallographic microscope. (K. 38.)

Pickling. The process of chemically removing scale or oxide from metal objects, to obtain a chemically clean surface. This is usually effected by immersion in an acid bath. For steel, the acids generally employed are sulphuric and hydrochloric to which is added an *inhibitor* (*restrainer*). An inhibitor consists of an organic material such as glue, starch or various proprietary compounds which are often organic derivatives containing nitrogen, oxygen, sulphur or other elements of the fifth and sixth Periodic Groups. It is added in small quantities, often about 0·05%, or slightly more, to reduce or restrain the attack of the acid on the metal and so effect the removal of the scale with a minimum loss of metal. Inhibitors may be of a foaming or non-foaming type, the object of the former being to produce a blanket of foam on the surface of the pickling bath with the object of reducing acid spray caused by the bursting of bubbles of hydrogen at the surface. In recent years, increasing use has been made of treatment in molten caustic soda baths with additions of sodium hydride or other salts. This treatment is followed by water quenching and if required a brief acid dip. Materials otherwise difficult to pickle may often be rapidly and efficiently descaled in this way. (See also ELECTROLYTIC PICKLING and SODIUM HYDRIDE DESCALING.)

Pickling Brittleness. (See ACID BRITTLENESS.)

Pickling Test. This consists of immersing the specimens for several minutes in dilute sulphuric acid. The acid removes the scale from the bar and exposes to view such surface defects as may be covered or hidden by the scale.

Pickup. In cold drawing of tubes the adhesion or partial welding of particles of steel from the tube to the surface of the die or plug.

Picral. An etching reagent consisting of a 2% to 5% solution of picric acid in ethyl alcohol. It may be used for plain carbon and low alloy steels.

Picture Frame Malleable. A *malleable iron* with completely graphitized *core* and a crystalline edge containing *pearlite*. (J. 12.)

Piercer. (See VENT WIRE.)

Piercing. (*a*) The process of spinning and rolling a billet over a mandrel in such a way that a hole is opened in the centre. It is the first operation in the production of a seamless tube from a billet and is basically a forging operation, in which the metal is worked from the inside as well as the outside. As the tube is pierced whilst spinning at a high rate, there is considerable metal displacement which results in a refined grain structure and uniform grain flow. (*b*) Opening a hole through a billet by hot *punching*.

Piezo-Electric Effect. The phenomenon discovered by Pierre and Jacques Curie in 1880, in which crystals of certain minerals or salts, when subjected to an electric charge, expand and contract under the influence of these charges. Conversely, these materials when subjected to alternating compression and tension, set up alternating electric charges. Such crystals may be

made to vibrate at frequencies of from 0·02 to 50 megacycles per second. It is this latter effect which is used in flaw detecting instruments in *ultrasonic tests*. (R. 49.)

Piezometer. An instrument for determining *compressibility* of a substance.

Pig. A mass of metal (e.g. *cast iron, copper* or *lead*) cast in a simple shape, and subsequently remelted for purification, alloying, casting into final shape, or into ingots for rolling.

Pig and Ore Process. A method developed by *Siemens* for the production of steel from pig iron in the *open hearth furnace*, the carbon content of the pig iron being oxidized by additions of iron ore.

Pig and Scrap Process. A modification of the *pig and ore process* devised by the Martin Bros. in France, in which the iron ore was replaced by scrap steel, thus lowering the total carbon content of the charge and so decreasing the degree of oxidation required.

Pig Bed. (*a*) Small excavations or regularly made open sand moulds in the floor of the foundry to hold the excess iron in the heat. (*b*) A similar arrangement of open sand moulds made to receive the molten *pig iron* from a *blast furnace*, but as regards blast furnace practice, this is now largely superseded by other devices, as for example, the *pig casting machine*.

Pig Boiling. The process of *puddling*.

Pig Casting Machine. An appliance consisting of an endless chain of water-cooled moulds, which provides for the continuous and rapid casting of molten pig iron.

Pig Iron. Crude iron produced by the reduction of iron ore in a *blast furnace*, and cast into *pigs* which are used for making steel, cast iron, or wrought iron. The principal impurities are carbon 2·5% to 5%, and varying amounts of silicon, manganese, sulphur and phosphorus. The composition varies according to the type of ore, *smelting practice*, and the purpose for which the iron is to be used. (See also Sow and Cast Iron.)

Pig Iron Desulphurization. (See Kalling-Domnarfvet Process.)

Pig Machine. (See Pig Casting Machine.)

Pigging Back. The addition of *pig iron* to the bath of the *open hearth furnace* to ensure a satisfactory *boil* or to increase the carbon content to the desired amount. The reverse process is that of *oreing down*, in which ore is fed in to effect oxidation of the carbon.

Pike Process. A method for the direct production of steel by passing reducing gases over iron oxide ore, carburizing the reduced ore, and alloying it in an electric furnace. Thus, a reducing gas, heated to 900° C. is passed over iron oxide ore to produce metallic iron, and spent gas. Part of the spent gas is cooled, dehumified and freed of CO_2, and again passed through the hot, partially reduced iron oxide which converts CO to CO_2 + C. Inert gas is used to cool the carburized iron which contains about 90% of metallic iron with sufficient C to effect reduction of the remaining iron oxide. The carburized, partially reduced metal is melted, reduced and alloyed in the electric furnace.

Pile Side. The left side of a knife when it is held with the blade pointing away, and the cutting edge downwards. It is the side on which it is customary to put the trade-mark.

Pilfer Proof. The degree of tightness adopted in the assembly of screwed sockets to prevent their being readily removed by hand.

Pilger Process. (See Pilgrim Rolling.)

Pilgrim Rolling. A step rolling process in which the work is caused to pass through the rolls step by step, making a certain amount of real progress at each stroke. It is used for the production of seamless tubing by the *Pilger Process*. (Pilger being a German word meaning pilgrim.) After cylindrical billets are pierced, the rolling process differs fundamentally from the usual method of completing tubes. The elliptical rolls, used to form the tubing, rotate in a direction opposite to the feed of the steel which is pressed against the rolls by a ram. The steel is fed forward by the ram when the pass between the rolls is wide. The rolls have a groove tapered to a decreased diameter over part of their surface while the remainder will permit free passage of the billet. The bloom, with an inserted *mandrel* or *broach*, is forced into the rotating rolls and is advanced and rotated specific amounts at intervals corresponding to the passage of the decreased diameter part of the rolls. A short section of the billet is reduced during each revolution. (B. 54.) (J. 10.)

Piling. (*a*) *Mill Pile*. A number of bars of wrought iron placed one on top of the other, ready for heating to a welding temperature and rolling into bars and sections. (*b*) *Ball Furnace Pile*. A suitably arranged pile of scrap which after heating to a welding temperature is hammered into a solid bloom for rolling into semi-finished forge bars. (*c*) A form of rolled struc-

tural shape of two types: sheet piling, and bearing piling. The three forms of sheet pile—straight, arch type and zee—are used for such types of construction as docks, breakwaters, coffer dams, etc. Bearing piles, which range from 14 in. to 8 in. in depth, are heavy, wide flange sections for foundation work, etc.

Piling Up. The condition produced on a surface by the penetration of the ball in indentation hardness testing, in which the perimeter of the surface of contact of the indenter and the specimen is above the original level.

Pillow Test. A method of determining both the strength and pressure tightness of welded seams. The pillow test specimen is constructed from two sheets of steel and/or metal, and prior to welding, a small hole is drilled in the centre of one sheet to which is welded a pipe nipple. The sheets are then seam welded together along the edges so as to enclose a 4 × 4 in. area. The specimen is then attached to a hydraulic system and the hydrostatic pressure gradually increased until rupture occurs. The pressures in pound per sq. in. at which rupture occurs are recorded together with details of the location of the fracture, in the seam. (N. 16.)

Pilot Arc System. A method which permits stud welding through paint and scale. It also obviates sticking of the stud to the plate before the normal welding arc is formed. This is often caused by high contact resistance due to dirty plate. In this system a pilot arc of low intensity is produced through a suitably disposed inductive loading coil, which allows the welding current to circulate only when satisfactory electrical contact has been established between stud and plate.

Pilot Drill. The reduced cutting portion in the form of a drill at each end of the tool extending from the chisel edge to the countersink.

Pimpling. A defect sometimes seen in higher carbon austenitic chromium nickel steel sheet of the 18/8 type. It is due to the segregation of carbides and appears in the form of clusters of lighter coloured spots.

Pinch. (*Jump.*) An overlap in a sheet caused by uneven heating of a pack of sheets prior to *pack rolling*.

Pinch Effect. The radial compressive force resulting from a high current passing through a molten globule of metal, e.g. in welding, which tends to pinch the molten globule and detach it from the electrode. (A. 37.)

Pinch Pass. (See SKIN PASS.)

Pine Tree. (See DENDRITE.)

Pinhole Porosity. (See PINHOLES.)

Pinholes. (*a*) Minute *gas cavities* fairly uniformly spaced throughout a casting and due to the liberation of occluded gas. They are found chiefly in light alloy castings. (*b*) Small round holes used to define beams of X-rays.

Pinion. The smaller of a pair of cogged wheels which engages with the larger one. In a rolling mill, the term pinion is applied to the broad-faced steel gears situated between the rolling mill motor and the driving spindles.

Pins. (*a*) The projections on the *drag* of a *flask* which guide and hold it in position with relation to the *cope*. (*b*) Cylindrical bars, sometimes tapered (taper pins) for joining two parts together, e.g. a boss to a shaft. (See also GUDGEON PIN.)

Pintadoite. ($2CaO.V_2O_5.9H_2O$.) A vanadium ore.

Pintsch Process. A method for the production of *single crystal* tungsten wire. A squirted filament is drawn slowly through a point at which the temperature is raised to 2000° to 2200° C. A large crystal develops which occupies the whole section of the wire and this is slowly drawn through the heated zone, the small grains being absorbed by the large crystal already formed. If the rate of travel does not exceed the rate of crystal growth the whole wire is converted into a single crystal which is wound on a spool.

Piobert Effect. The effect obtained when a highly polished bar of iron or soft steel is loaded in tension and a value of the stress is reached at which the bar may suddenly yield to a remarkable amount, and this is seen to be accompanied by characteristic permanent surface distortion. The distortion figures have been named "lines" of *Piobert, Lüders* and *Hartmann, strain figures,* and *stretcher strains* and *worms*. The distortion is partially shown by flaking-off of surface scale dislodged by the distortion of the metal and, on sections, by *Fry lines*. (F. 11.)

Piobert Lines. (See PIOBERT EFFECT.)

Pipe. (*Contraction Cavity, Shrinkage Cavity, Tube.*) An axial cavity produced in the ingot by the contraction of the steel on freezing. When the pipe is in the top or open part of the ingot it is known as *primary pipe* and when it appears in the lower part it is described as *secondary pipe*.

Pipe Smoother. A moulding tool used on cylindrical surfaces.

Piping. (*a*) The production, during the solidification of an ingot or other massive casting, of a *pipe* or pipes. (*b*) Synonymous with tubes or pipes, but

the term is more commonly restricted to assembled pipework.

Piping Steel. (See KILLED STEEL.)

Pit. (*a*) A local depression in a metallic surface caused by corrosion-attack over a minute area. (*b*) (See CASTING PIT). (See also SOAKING PIT.)

Pit Sample. A sample of metal taken during the *teeming* of the steel in order to determine the chemical composition of the cast.

Pitch. The name given to numerous hard, dark substances which melt to viscous, tarry liquids; applied to the residue from the destructive distillation of wood and coal-tar, to asphalt and various bitumens.

Pitch Line. In a rolling mill, a line locating the centre of gravity of the various passes; it is usually placed midway between the axis of rotation of the two rolls.

Pitchblende. A mineral consisting essentially of uranium; it is one of the chief sources of radium.

Pitot Tube. An instrument for measuring the velocity of a current of water or gas. In the case of the former, the device consists of an L-shaped glass tube, the lower horizontal limb being placed in the water, the velocity of the stream being determined by the height to which the water rises in the vertical limb. In the latter case it consists of a manometer whose nozzle is placed at right angles to the flow of the air current. This instrument, in addition to measuring the velocity of an air current, can also be used to determine static pressure.

Pitting Corrosion. Localized attack in depth rather than area which may be caused by segregation of alloy components, carbide precipitation due to incorrect heat treatment, inclusions of slag or scale, local concentration of the corrosive, or by stressing set up by mechanical working. It occurs more frequently in stagnant solutions. Certain types of corrosives such as chlorides and other *halides* tend to cause pitting in stainless steels.

Pitting Factor. The depth of the deepest pit resulting from corrosion divided by the average penetration as calculated from weight loss. (E. 10.)

P.L.A. Port of London Authority.

Plain Butt Weld. A joint made by the *resistance butt welding* of two parts of similar cross-section.

Plain Carbon Steel. (See CARBON STEEL.)

Plain Ends. Ends of tubes which are cut at right angles to the longitudinal axis and without additional workmanship. . .

Plain Thermit. (See THERMIT.)

Plan Approach Angle. (See RAKE.)

Plan Trail Angle. (See RAKE.)

Plane. In crystallography, a possible face of a crystal.

Plane of Symmetry. In a crystal, a plane in which a reflection, with or without a translation parallel to the plane, replaces every element (point, line and plane) of the crystal, by an equivalent element. The plane is a *reflection plane* if no translation is involved, and is a *glide-reflection plane* if translation is involved.

Planetary Rolling Mill. A mill in which metal strip is produced from a flat slab, in a heavy single-pass reduction, by the action of a succession of pairs of work rolls. Each roll comes into contact with the slab at an oblique angle and leaves it parallel with its surface; the individual roll produces a relatively small reduction. Heating, due to the work done in reduction, is sufficient to off-set heat losses by radiation and convection. Opposite rolls of each pair have a planetary movement about a fixed point, and the angle of contact is so great that a back fin is formed of metal removed from the surface of the slab. *Clad metal* strip is produced by feeding at the same time a strip of another metal at a temperature initially lower than that of the slab, the joining surface of the strip and the slab being moved with respect to one another under pressure. (S. 39.)

Planetary Thread Rolling. A method, by the cold forging process, of producing threads or other forms on a round blank with a continuous motion in a path around a rotary die. (P. 49.)

Planimeter. An instrument for the mechanical measurement of areas.

Planimetric Method of Grain Count. (See INTERCEPT METHOD.)

Planishing. The production of a superior finish on a previously rolled or forged product. This is accomplished by passing the bar or other product through chill cast or hardened steel rolls or by hammering with a smooth-faced hammer.

Planishing Pass. A *finishing pass* which may be applied, for example, with the object of flattening a weld *bead*.

Plaster. (See DOUBLE SKIN.)

Plaster of Paris. Powdered calcium sulphate obtained by calcining *gypsum*.

Plastic. A synthetic material chiefly characterized by the fact that it consists of a resin or some other organic binder, and that at some intermediate stage in its production it is capable of being cast and that eventually it becomes rigid. Certain types are *thermo-*

plastic, whilst others are *thermo-setting*. (B. 57.)

Plastic Body. (See ELASTIC BODY.)

Plastic Clay. Any clay which, when ground finely and wetted with water, is sufficiently plastic to be useful for bonding non-plastic grains. Most commercially useful clays comply with these requirements and such clays may also be further identified by such terms as *fireclay*, *pot clay*, *bentonite*, etc.

Plastic Deformation. Permanent deformation. (Cf. DEFORMATION.)

Plastic Dipping. A method of protecting steel or metal parts during storage, or transit, by dipping in ethyl-cellulose plastic. (F. 27.)

Plastic Flow. The deformation of metals by the mechanism of *slip* along definite geometric planes within the *crystals*.

Plastic Replicas for Surface Finish Measurement. In this method, the plastic in liquid form is placed on the previously cleaned metal surface under examination. When dried it is stripped off and examined by means of an instrument specifically designed for that purpose, e.g. a *Talysurf*. (P. 15.)

Plastic Strain. The permanent deformation after removal of load, synonymous with *permanent set*.

Plastic Welding. (*Forge Welding*.)

Plasticarve. A low-melting compound used in modelling or duplicating patterns. (D. 26.)

Plasticity. That property of a body by virtue of which it tends to retain its deformation without rupture after removal of the applied deforming stress. The term defines the ease of deformation.

Plastometer. A machine for the determination of the stress/strain properties of metals at high temperatures and at various rates of strain.

Plate. (*a*) A flat piece of steel or other metal obtained by rolling, and usually over $\frac{1}{8}$ in. in thickness. In some classifications, however, sheet includes the $\frac{3}{16}$ in. thickness, plate starting at $\frac{1}{4}$ in. (*b*) In *powder metallurgy*, flat particles of metal powder having appreciable thickness.

Plate Feeder. A sand-feeding device consisting of a power rotated flat plate mounted below a cylindrical or conical sand hopper. A plough scrapes the sand from the rotating plate in a uniform stream.

Plate Moulding. A production process for shallow work. Half the pattern may be fixed on each side of a flat plate.

Plated Bars. (See CEMENTATION.)

Plated Hearth. Freezing of the bottom portion of the pool of metal in the furnace hearth.

Platen. The work-table of a machine tool, e.g. of a planing machine. It is usually slotted to receive bolts to clamp the work to the machine.

Platen Force. In *flash-* and *upset-welding*, the force available at the moveable platen to cause upsetting. This force may be dynamic, theoretical or static. (A. 37.)

Plating. (*a*) (See ELECTROPLATING). (*b*) A forging operation so designed that the spread of the metal is in the transverse rather than in the longitudinal direction. (*c*) In forging cutlery, to finish the hammering with light blows, when the work is at a minimum temperature, to produce a smooth surface.

Plating Brittleness. A term used in the U.S.A. for *hydrogen embrittlement*.

Platinum. (*Pt.*) *Atomic weight* 195.23. *Specific gravity* 21·4. *Melting point* 1773° C. A hard silvery-white ductile and malleable metal. It is very resistant to heat and acids and has a coefficient of expansion very nearly equal to that of glass. It occurs as the metal, and also in association with other metals, such as *osmium* and *iridium*. It is used for electrical contacts, scientific apparatus, as a catalyst and in jewellery. In instrument practice, one of the most widely known applications of platinum and its alloys is the *platinum/platinum-rhodium thermocouple*.

Platinum Metals. The six rarer elements in Group VIII of the periodic system which normally occur together in nature and resemble each other in properties. They comprise *ruthenium*, *rhodium*, and *palladium*, *osmium*, *iridium* and *platinum*.

Platinum/Platinum-Rhodium Thermocouple. A *thermocouple* for high temperature measurement consisting of two wires, one of pure platinum and the other of an alloy containing 90% platinum and 10% rhodium, or 87% platinum and 13% rhodium. The wires are welded together at one end to form the *hot junction*. With this couple and using the *quick immersion method*, accurate measurements of the temperature of liquid steel may be made up to above 1600° C.

Platinum Resistance Pyrometer. (See PYROMETER.)

Platter. In forging, the entire mass of metal upon which the hammer performs work. It includes the *flash*, *sprue* and *tonghold*.

Plug. (*a*) (See CRUCIBLE). (*b*) (See PLUG DRAWING).

Plug Die. (See FLOATING PLUG.)

Plug Drawing. A term used in the production of cold finished and seamless tubes, where a stationary plug, i.e. a

short stem screwed into a long *mandrel* is held in the orifice of the *die*. This is inserted into the tube before *drawing* and the outside and inside diameters of the resultant tube are determined by the size of the die and the plug respectively. Only a short plug, a little longer than the die width, is used, and this alone has to be finished to close limits. The bar, which retains it in position in the die, need only possess the requisite physical strength; its surface finish and metallurgical composition are unimportant. The plugs, which are screwed on to the plug bars, are either of tungsten carbide, as is usually the case with the dies, or else of alloy tool steel, with a hard chromium finish. The process is principally employed for the production of highly finished bores. (M. 50a.)

Plug Lines. Longitudinal lines in the bore of a cold drawn tube caused by localized seizure between the tube and the plug during *plug drawing*.

Plug Mill Process. (See AUTOMATIC PLUG MILL PROCESS.)

Plug Welding. A method of attaching a lining by welding it to the base plate through holes punched or drilled through the liner. The holes, which vary in size according to the thickness of the liner, are filled with weld metal which bonds to the base plate and to the liner around the edges of the hole. (A. 37.)

Plugged Impressions. In *sand moulding*, impressions formed by inserting a plug of the required shape through a pattern into the sand. (A. 26.)

Plugging. (See CAPPING.)

Plumbago. (*Black Lead.*) (*a*) *Graphite* in powdered form. The natural allotropic form of carbon. (*b*) A refractory material in which graphite is an essential element.

Plumbago Crucibles. Highly refractory *crucibles* composed of a mixture of about equal parts of refractory clay and graphite. In the *crucible process*, these were more generally used in the U.S.A. than in the United Kingdom.

Plumber's Solder. Usually a mixture of lead and tin, sometimes with a little antimony. Coarse solder contains 75% lead and 25% tin, and melts at 250° C. Ordinary solder (*slicker solder*) usually consists of 67% lead and 33% tin and melts at 227° C. Plumber's fine solder, or soft solder, contains 50% lead and 50% tin, and melts at 188° C.

Pluramelt Process. (*Hopkins Process.*) A process developed to face carbon steel ingots with stainless, tool or other alloy steels. Either slabs or ingots of carbon steel are fastened into the Pluramelt machine and any desired thickness of alloy steel is continually built up on one or more surfaces. (See also KELLOGG ELECTRIC FUSION PROCESS.) (L. 36.)

Plurial Arc Welding. A method of arc welding, in which a bundle of fusible, coated electrodes is used, the electrodes being automatically ignited in rapid succession at regular intervals. The process can be applied to the welding of all kinds of structural steels, and to stainless steels. It can only be carried out horizontally. The mechanism of the process depends on ionization of the electrode coating, the electrode with the most ionized coating being ignited first. (L. 16.)

Plus Mesh. The particles of a powder sample retained on a screen of stated size.

Plutonium. (*Pu.*) *Atomic weight* 242. *Atomic number* 94. Plutonium 239 is a fissionable material which is suitable for use in either power production or atomic weapons. It does not occur naturally and is made by bombarding *uranium* 238 with *neutrons*. This forms uranium 239 which decays first to *neptunium* 239 and then plutonium 239. Chemical separation is required to remove the plutonium from the excess uranium and its fission products. It is in group III of the *periodic system*.

Ply Metals. Sheet consisting of bonded layers of dissimilar metals. (See CLADDING.)

Ply Rolling. (See PACK ROLLING.)

P.M.I. Pressed Metal Institute (U.S.A.).

Po. Chemical symbol for *polonium*.

P.O Bridge. (See POST OFFICE BRIDGE.)

Pohlman Method. (*Visible Sound Method.*) A technique for the *ultrasonic testing* of steel in which a visible image of the defects present in the steel can be shown on a screen. The lens for separating the interrupted waves from the transmitted waves so as to obtain a shadow image, consists of a cell containing a suspension of minute bright metal flakes (about 10 μ in diam. and 1 to 2 μ thick) in chloroform or carbontetrachloride in a flat capsule having a metal foil as one face and a rigid disc of glass as the opposite face. This cell is pressed against the metal to be examined, and is opposite to the quartz transmitter. The minute flakes in the path of the transmitted waves arrange themselves parallel to the wave front whilst those in the shadow of the defect remain in random order. Using a suitable light source an image of the defect can be projected on the screen. An apparatus utilizing these principles, and having a wide range of

practical application has been constructed. It consists of two columns mounted on a stand. The rear column holds the high frequency quartz transmitter with its controls, and it can be moved and clamped in position on the stand so that objects up to 500 mm. thick can be placed between the two columns. The other column carries the receiving apparatus, projector, screen, controls, and compressed air device for pressing the lens against the metal face. The image can be focused and the adjustment of this indicates the depth of the defect from the surface. The apparatus has a range of application for detecting defects down to 0·5 sq. mm. in area and 10^{-3} to 10^{-4} mm. thick. (P. 27.)

Point. In printing, the standard unit of type size approximately one seventy-second part of an inch. All type sizes are now multiples of this unit.

Poise. A unit of *viscosity*.

Poisson's Ratio. (*Rho Ratio.*) The ratio of the transverse contraction per unit dimension of a bar of uniform cross-section to its elongation per unit length, when subjected to a tensile stress.

Poke Welding. (*Push Welding.*) A modification of *spot welding* which involves the use of a pistol carrying a tungsten electrode in the centre of a water-cooled copper cup. The cup is pressed against the outer of the two surfaces to be welded and the end of the electrode is $\frac{3}{32}$ in. from the work. On pressing the trigger, a solenoid-operated valve admits argon to the cup and a high frequency current is superimposed on the welding current to ionize a path between the electrode and the work. A pre-set timing device shuts off the welding current and a second device stops the flow of argon after 10 or 15 seconds. The method is suitable for use in awkward positions where the sheet metal is accessible on one side only, and it can be employed for both stainless and mild steel. (P. 23.)

Polarity. (*a*) A term applied to electrical machinery or apparatus when it is desired to indicate which terminal is positive and which is negative. (*b*) The quality of an electrical charge, i.e. whether it is positive or negative.

Polarization. The production of counter-e.m.f. by products formed or by concentration changes resulting from passage of current through an electrolytic cell. (E. 10.)

Polarized Light. (See POLARIZERS.)

Polarizers. Special materials such as *Nicol prisms* and Polaroid sheet which transmit light vibrations predominantly in one direction. Light waves are transverse, which means that ordinary light radiation consists of many vibrations lying in all directions cross-wise to the beam of light. This is unpolarized light. *Polarized light* consists of light waves which have passed through a polarizer and hence the vibrations in one direction predominate over those in other directions.

Polarizing Pyrometer. This type of pyrometer, first designed by Wanner in 1901, is so constructed that when sited on to a hot body the light from that body passes through a slit in the front of the instrument. Light from a comparison lamp is totally internally reflected in a prism and then passes through a second slit situated below the first, the two beams being rendered parallel by a lens. Monochromatic light is produced by means of a direct-vision spectroscope and screen, cutting out all but a narrow band in the red. Each of the beams is next separated by a *Rochon prism* into two beams polarized at right angles. A second achromatic lens focuses the beams on to a slit in front of a *Nicol analyser*, and a biprism produces a deviation in the beams so that two images, one from each source, are brought into juxtaposition. All the other images are screened out. The Nicol analyser is attached to the eyepiece so that it can be rotated about the optical axis. If the two beams are of unequal intensity it can be rotated between 0° and 90° until the field is uniformly illuminated. The degree of rotation of the *Nicol prism* is calibrated to give directly the temperature of the source uncorrected for emissivity. (H. 34.)

Polarogram. (See POLAROGRAPH.)

Polarograph. An instrument used in chemical analysis. It measures the current which flows when a predetermined potential is applied to two electrodes immersed in the solution being analysed. The equipment consists of an electrolytic cell with dropping mercury electrode, a potentiometer for applying a voltage to the cell, a galvanometer for measuring the current passing through the cell, and a camera for recording the fluctuations and voltage. The technique is based on the fact that if a solution containing metal salts is electrolysed, using a pool of mercury as the anode and mercury dripping from a capillary tube as the cathode, as the applied voltage is increased, the current does not increase proportionately but rises in a series of steps, each corresponding to a particular metal ion. Under suitable chemical conditions, the current is a linear function of the con-

centration of the reducible ions in solution. Curves obtained by this means are called *Polarograms* and both the concentration and species of the substance in solution can be directly determined from the character of the curves. The method can be used, for example, in steel analysis for the determination of small quantities of metallic impurities. (D. 15.)

Poldi Hardness Tester. (*a*) A light, portable instrument based on the Vickers principle. The impression is obtained by a spring-loaded diamond pyramid with a tip angle of 136°. The spring preloading is usually set to 30 kg. Other preloading values can be obtained by inserting distance pieces and one for a preloading value of 10 kg. is supplied with the instrument. The impression measuring device is swivel-mounted on the ocular of the microscope, permitting measurement of both diagonals. After making an impression, the microscope is moved into position by a simple swivelling and lowering operation. The hardness values are obtained from tables as with a *Vickers Hardness tester.* Specimens up to 150 mm. thick are tested on a supporting plate, for larger parts this plate is removed and the tester is placed directly on to the object. (D. 37.) (*b*) A *hardness comparator* in which a 10 mm. ball in a suitable holder is given a blow so as to make an impression in a standard test piece as well as on the piece tested.

Pole. The part of a magnet, usually near the end, towards which the lines of magnetic flux apparently converge or from which they diverge.

Pole Figure. (For crystalline aggregates.) A stereoscopic projection showing preferred orientations of the normals to planes of a given form.

Polianite. A mineral consisting essentially of manganese dioxide (MnO_2).

Poling. Stirring molten metal, particularly copper, tin and zinc, either in a furnace or in a ladle, with a pole of green wood. The heat distils off the volatile products which stir up the metal, and together with the charcoal formed, helps to reduce any oxide present. The condition of the melt may be referred to as *underpoled* or *overpoled* according to its degree of stirring.

Polish Attack. A method of developing the *microstructure* of a metal by combining the *etching reagent* with the polishing medium. It was particularly used in the early development of microscopic *metallography* by *Osmond* in France.

Polonium. (*Po.*) Radium-F. *Atomic weight* 210. *Atomic number* 84. A radioactive metal. It is a last stage element in the radioactive disintegration of radium to lead.

Polychromatic. Having several distinct wave-lengths; for example, the characteristic X-rays from a single element.

Polygon. Plane figure bounded by several (more than four) sides.

Polycrystalline. A solid, composed of several or many crystals, as contrasted with one that is a single crystal. Metals in normal use consist of an aggregate of crystal grains and are, therefore, said to be polycrystalline.

Polygram Casting. A process for the production of metal patterns from ferrous metals for use in the manufacture of moulds or cores, by investing a heated pattern with a finely divided moulding material containing sand and a finely divided thermo-setting plastic material, for example a hardenable phenol resin. A hollow pattern or core is first formed by depositing a coating of a metal on a master pattern, e.g. by electrodeposition or spraying, thus controlling the thickness in accordance with the heat storage capacity required in the finished pattern or core, when the master pattern is removed. (P. 31.)

Polyhedron. A solid figure bounded by any number of plane faces.

Polymorphism. An effect akin to that of *allotropy* by which metals or intermetallic compounds which are chemically similar, differ in crystal form, and change from one form to another at a definite temperature. Those existing in two varieties are known as *dimorphous*, and those with three varieties as *trimorphous*.

Polyoptrum. A lens, one side of which is plane and the other convex.

Pomey and Voulet Hardness Tester. An apparatus for the measurement of both very high and very low hardnesses. The indenter consists of a sharp-pointed diamond cone, the angle of which is 136°. Special means are incorporated to enable the load to be applied very gently. The indentation having been made, the indenter and its support are moved aside and a high-power microscope is moved into place to measure the diameter of the indent. (P. 32.)

Pontalite. Methyl methacrylate, found satisfactory for the mounting of small metallurgical specimens. Originally in the form of powdered resin, under temperature and pressure it becomes as transparent as glass. It is tough, hard and resistant to the action of etching reagents, and adheres excellently to the specimen. (E. 5.)

Poor Penetration. (See IMPERFECT ROOT PENETRATION.)

Pop Marks. (*Datum Points.*) (*Gauge Marks.*) The punch marks on a tensile test piece indicating the gauge length upon which the elongation is to be measured.

Pop-Up. An American term for a *blind riser.*

Pore. (*Void.*) In *powder metallurgy,* a minute cavity in a compact, formed either intentionally or unintentionally.

Pore-Forming Material. In *powder metallurgy,* a substance included in a powder mixture which volatilizes during *sintering* and thereby produces a desired kind of porosity in the finished compact.

Porman. An iron ore occurring in Carthagena. It sometimes contains *magnetite,* and usually has a low phosphorus content. Its iron content is about 55%, the gangue consisting chiefly of silica.

Porosity. (*a*) Unsoundness in castings caused by the presence of *blowholes* and *shrinkage cavities.* (*b*) The volume of the pore spaces or voids in sand. (*c*) In *powder metallurgy,* a multiplicity of *pores* or *voids* usually distributed uniformly and between the metal particles of the *powder compact,* and usually expressed as a percentage of the total volume of the part. *Intercommunicating porosity* is that type of porosity in a *sintered compact* in which the pores are intentionally connected, so that fluid may pass from one to another, or completely through. (*d*) A spongy condition of weld metal due to the presence of numerous *blowholes.*

Portable Cover Furnace. An annealing furnace in which the furnace itself and the inner cover that envelops the stock to be heated, are portable. The coils to be heated are stacked on a pedestal on the furnace base and a light fabricated steel inner cover is placed over them. The furnace is then placed over the inner cover. Normally, each furnace is provided with three fixed bases, one loading, one heating, and one discharging, so that the furnace can be in constant operation. The furnace is constructed of welded steel plate, supported and stiffened by structural steel members. The sides are lined with insulating refractory material. A sprung arch, suitably insulated, is used. It is claimed that with radiant-tube firing, the furnace brickwork requires relatively little maintenance and should have a life of more than six years. (D. 10a.)

Porter Bar. A bar used for the manipulation of ingots during forging.

Portevin-Le Chatelier Phenomenon. The occurrence of discontinuities in load-extension curves. (B. 70.)

Porthole Die. A type of extrusion die consisting of two or more sections and used to extrude shapes that have unusual contours. The metal is extruded as several different streams, which are welded when they leave the die, to form tubing and intricate closed shapes without requiring the use of separate mandrels.

Ports. The openings over the hearth of a *regenerative furnace,* through which the air and gas enter and the products of combustion leave.

Porus-Krome Process. (See VAN DER HORST PROCESS.)

Positron. Particles of electricity equal in mass to the *electron* but having a positive charge of electricity equal and opposite to that on the electron. It has only a transitory existence under terrestrial conditions.

Post Heating. A heating operation applied to *welds* as soon as possible after welding for the purpose of relieving stresses and of *tempering* the weld metal and heat affected zone.

Post Office Bridge. (*P.O. Bridge.*) A self-contained combination of resistors connected for use as a *Wheatstone Bridge.*

Post-Pressure Welding. (See PRE-PRESSURE WELDING.)

Post Test. (See AIR HARDENABILITY TEST.)

Pot. (*a*) A crucible for holding molten metal. (*b*) (See POTT).

Pot Annealing. (See BOX ANNEALING.)

Pot Clay. The name applied in the Sheffield district to a particular seam of plastic clay which is extensively used for making fireclay pit refractories (*stoppers, nozzles, runners, guides,* rod covers, etc.) and for bonding non-plastic materials (*grog*) to make feeder head *compo,* etc. Pot clay contains about 14·5% of combined water and about 38% alumina when calcined.

Pot Hole. (See CRUCIBLE PROCESS.)

Pot Mould. The mould used in making *crucibles* for use in the *crucible process.*

Pot Quenching. A process of quenching carburized parts directly from the *carburizing* box or pot. (A. 28.)

Pot Steel. Steel made by the *crucible process.*

Potassium. (*K.*) *Atomic weight* 39·100. *Melting point* 62·5° C. Boiling point 770° C. An alkali metal reacting violently with water. As a metal it has little commercial use other than as a laboratory reagent. Its salts are used extensively.

Potassium Dichromate. ($K_2Cr_2O_7$.) A red, crystalline, soluble salt, prepared

from chrome iron ore, used as an oxidizing agent, and in the paint and dye industries.

Potassium Hydroxide. (*Caustic Potash.*) (KOH.) A white, deliquescent solid, which dissolves in water to give an alkaline solution.

Potassium Nitrate. (KNO_3.) A white, soluble, crystalline salt. When hot, it acts as an oxidizing agent.

Potassium Permanganate. ($KMnO_4$.) Deep purple, crystalline, soluble salt, dissolves in water to give a purple solution which acts as a powerful oxidizing agent. It is used as a disinfectant and analytical reagent.

Potential Difference. A difference in the electrical states existing at two points, which causes a current to tend to flow between them. It is measured by the work done in transferring a unit charge of electricity from one point to the other.

Potential Energy. Energy possessed by a body in virtue of its position. A body of mass m, at a height h above the ground, possesses potential energy mgh, since this is the amount of work it would do in falling to the ground. A body in a state of tension or compression (e.g. a coiled spring), also possesses potential energy.

Potential Series. (See ELECTRO-CHEMICAL SERIES.)

Potentiometer. An instrument for the measurement of electric quantities which depends for its operation upon the balancing of an unknown *potential difference* against a known potential difference obtained by the passage of a fixed current through an adjustable resistor or of an adjustable current through a fixed resistor.

Pott. (*Pot.*) A size of paper 12½ in. × 15 in. named after the original watermark of a pot. (See also BOOK SIZES.)

Potter Process. A method of *galvanizing*, patented in 1931, which introduced fused salts on the exit end of the bath. The claims made for this process were that by the use of fused salts a nitrogenized skin was formed on the wire.

Poumay Cupola. A type of *cupola* characterized by its small main *tuyeres* and subsidiary preheating tuyeres. It is designed for use in the steel foundry.

Pound. The mass of the *imperial standard pound*, a platinum cylinder kept at the Board of Trade Standards Office. 1 lb. = 453·592 gm. (See Appendix II.)

Pound Calorie. (See POUND DEGREE.)

Pound Degree. The heat required to raise one pound of water through one degree of temperature. A pound degree Centigrade, also known as the *Centigrade heat unit* or the *pound calorie*, is the heat required to raise 1 lb. of water through 1° C., whilst a pound degree Fahrenheit is the heat required to raise 1 lb. of water through 1° F.

Pound Moles. (See MOLE.)

Pour and Cloud Points. The term as applied to oils refers to temperature limits below which the fuel cannot safely be used without danger of stopping oil lines, pumps and filters.

Pourcel, Alexandre. (1841–1934.) A French metallurgist. He was awarded the Bessemer Gold Medal, in 1909, in acknowledgment of his important contributions to the advancement of the science and practice of iron and steel metallurgy.

Poured Short. A casting which lacks completeness due to the mould not being filled. (A. 26.)

Pouring Basin. A basin in the *cope* into which the molten metal is poured and from whence it passes down the *gate*. (P. 1.)

Powder. Particles of matter characterized by small size, usually within the range of 1 to 1000 *microns*. (G. 30.)

Powder Cutting Process. A process in which an iron rich powder is blown into an oxygen stream from outside a preheating flame. This powder is heated to ignition temperature by the oxy-acetylene preheat flame. The ignition of the powder creates a high temperature reaction. As the cutting proceeds, a combined melting and fluxing action continuously removes any refractory oxides formed. It was originally applied for the cutting of materials such as high alloy steels which are oxidation resistant to the normal *oxy-acetylene* flame, but has now been extended to the scarfing of blooms and billets, to the cleaning of steel castings and to cutting non-ferrous metals and refractory materials. (W. 27.)

Powder Metallurgy. A metallurgical technique which permits the production of metallic articles of simple or complicated shape without the use of processes such as melting, casting, metal working, etc. Powders of the necessary particle shape and particle size are first produced and are then *tumbled* with pressing lubricants to achieve intimate mixing. Pressing in a steel or tungsten carbide die follows under pressures of 15 to 45 tons per sq. in. The *green compact* so formed is sintered at a temperature below the melting point of the base metal for a period generally of 30 to 60 min. A continuous-type furnace is employed, a protective atmosphere such as burnt town gas or cracked ammonia being provided to pre-

vent oxidation. If necessary, re-pressing is then performed to bring the part to the size required; the sintering and sizing operations may be repeated to give enhanced physical properties. Final treatments may include impregnation with oil to impart self-lubricating properties. Some products depend on controlled porosity in the finished part, e.g. porous bronze bearings can absorb 20% to 30% by volume of oil, and thus a continuous lubricating film is secured. To achieve high density, a porous powdered product may be impregnated with another metal, for example, the tensile strength of a porous iron part may be increased by the addition of manganese, copper, and aluminium. (See also HARD METALS.) (W. 54.)

Powder Method. A method of X-ray or crystal analysis, using a loose aggregate of small crystals with chaotic orientation, applied to methods using solid metals composed of crystalline aggregates. (See DEBYE-SCHERRER METHOD, and HULL METHOD.)

Powder Scarfing. (See POWDER WASHING.)

Powder Strip. Strip which has been rolled continuously by feeding soft iron powder (0·03% C.) from a hopper into the nip of a pair of rolls with axes parallel in a horizontal plane. The nature of the strip issuing from the rolls depends on the shape of the grains, the screen analysis, the width of the roll gap, and the diameter and speed of the rolls. The density of the pressed strip increases linearly with decreasing roll gap up to a critical value and then increases more rapidly. Increased rolling speed, up to a certain maximum which depends on diameter and roll gap, produces thicker strip with higher density. (N. 2.)

Powder Washing. (*Powder Scarfing.*) American terms for the *powder cutting process.* (F. 28.)

Powder Welding. A term sometimes used for *metal spraying* when powder metal is sprayed from a pistol to build up a worn part.

Power Gas. (See PRODUCER GAS.)

Power Reels. Drums for coiling strip and pulling it through rolls that are not driven. (See STECKEL MILL.)

Power Squeezer. A moulding machine in which sand is packed to the required density, by compressed air applied to the outer surface of the mould.

Power Wet Honing. A completely automatic method of *honing* where the stroke, the speed of the stroke and the speed of rotation are controlled and constant. In addition, oil is provided to serve as a coolant and a detergent. It is performed on a special machine, an automatic honer, which gives a finish of 10 to 20 micro inches, which corresponds approximately with the range of 10 to 16 micro inches, recommended by ring and car manufacturers. An additional advantage lies in the reduction of the cost of stones which do not break in the operation of the machine. (L. 21.)

Pr. Chemical symbol for *praseodymium.*

P.R. Process. (See PERIODIC-REVERSE CURRENT PROCESS.)

Praseodymium. (*Pr.*) A metallic element, a member of the rare earth group. *Atomic weight* 140·92. *Specific gravity* 6·63. *Melting point* 940° C. It closely resembles neodymium and occurs in the same minerals.

Pre-Arcing. (See PRE-SPARKING.)

Pre-Bore Quenching. (*Bore Lead Quenching.*) A treatment which involves a water quench of the bore for a certain period of time, prior to the simultaneous quenching of both bore and outer surfaces of hollow cylinders. (S. 96.)

Pre-Burning. (See PRE-SPARKING.)

Precipitate. (See PRECIPITATION.)

Precipitation. (*a*) The deposition of insoluble matter (*precipitate*), usually in a state of fine division, from solution by means of a chemical reaction. (*b*) The deposition of an element or compound from a solid solution, as for example, the deposition of *cementite* during the cooling of a *hypereutectoid steel.* (See also AGEING.)

Precipitation Hardening. (*Dispersion* or *Structural Hardening.*) (See AGEING.)

Precipitation Heat Treatment. *Artificial ageing* in which a constituent precipitates from a supersaturated solution.

Precision Casting. In this process, very accurate metal dies are used for the production of equally accurate patterns in wax (*lost wax process*) or frozen mercury (*Mercast*). The patterns are compacted in very fine refractory material by vibration in a suspension of the material, and the resulting mould dried and baked, during which process the pattern melts out. The molten metal is usually forced into the cavity and the ensuing casting very accurately maintains the dimensions of the pattern, and it is possible to cast small articles requiring little or no machining. A modification of this method is the *Osborn Shaw Process.* (See also A.R.D. PROCESS, "D" SHELL MOULDING, INVESTMENT and POLYGRAM CASTING, and ELECTRONICAST PROCESS). (J. 18.)

Preece Test. A method of determining the thickness of the zinc coating on galvanized iron wire. The method consists of noting the number of one-

minute dips in a solution of copper sulphate at 18° C. needed to produce an adherent deposit of copper—a sign that iron has been laid bare. The specimen is freed from grease before the test, washed in running water between each test and rubbed lightly to remove loose copper. (E. 89.)

Preferred Orientation. The condition in which the principal axes of the crystals composing a *polycrystalline* mass tend to lie in the same direction. This has an effect on the mechanical properties. (See DIRECTIONAL PROPERTIES.)

Preforming. The initial pressing of a metal powder to form a compact which is subjected to a subsequent pressing operation other than *coining*, or *sizing*; also, the preliminary shaping of a refractory metal compact after *presintering* and before the final *sintering*. (G. 30.)

Preheater. A furnace designed to heat steel, usually in ingot form, and nearly always from the cold up to a predetermined temperature when it is transferred to another furnace or a *soaking pit*, where the steel is heated to the rolling or forging temperature.

Preheating. A general term used to describe a heating applied preliminary to some thermal or mechanical treatment to reduce the risk of thermal shock on subsequent heating.

Prepared Town Gas Process. A method of producing a suitable carburizing atmosphere for the *case hardening* of steels by the treatment of town's gas in a separate gas plant and enriching it with a hydrocarbon gas.

Pre-Pressure Welding. In this type of welding, high pressure is applied before maximum temperature is reached, and in the *post pressure* method the order is reversed.

Prepurging. (See PURGING.)

Presintering. In *powder metallurgy*, preliminary heating of a *compact* at a temperature below that of the final *sintering*. Presintering is usually intended to give sufficient strength to allow handling, or to remove a binder or similar substance, by volatilization.

Pre-Sparking. (*Pre-Arcing*, *Pre-Burning*.) In *spectrographic analysis*, the discharge or burning period given prior to the exposure time in order to attain the best excitation conditions, this period being continuous with exposure time.

Press. (*a*) A machine used instead of a steam hammer for the forging of large parts. It consists essentially of a cylinder with a plunger or ram, moving vertically, and forced down by hydraulic pressure upon the part being shaped, supported upon a heavy anvil block. (See Plate XII.) (See also FORGING.) (*b*) In *powder metallurgy*, a machine used to form a *compact* by pressure. (*c*) A machine used in the manufacture of *pressings* from sheet material.

Press Forging. (See FORGING.)

Press Welding. A multi-spot welding method, where all the welding heads or guns engage with the work simultaneously and are fired electrically either at the same time, or successively in groups. Although the name implies that it is a welding process performed in a press, it is not necessary to have the welding electrodes mounted in a press, to have a press weld set-up. In fact the press itself is used only to raise or lower the work pieces into the welding position, and does not perform any of the normal functions usually associated with a power press. (S. 52.)

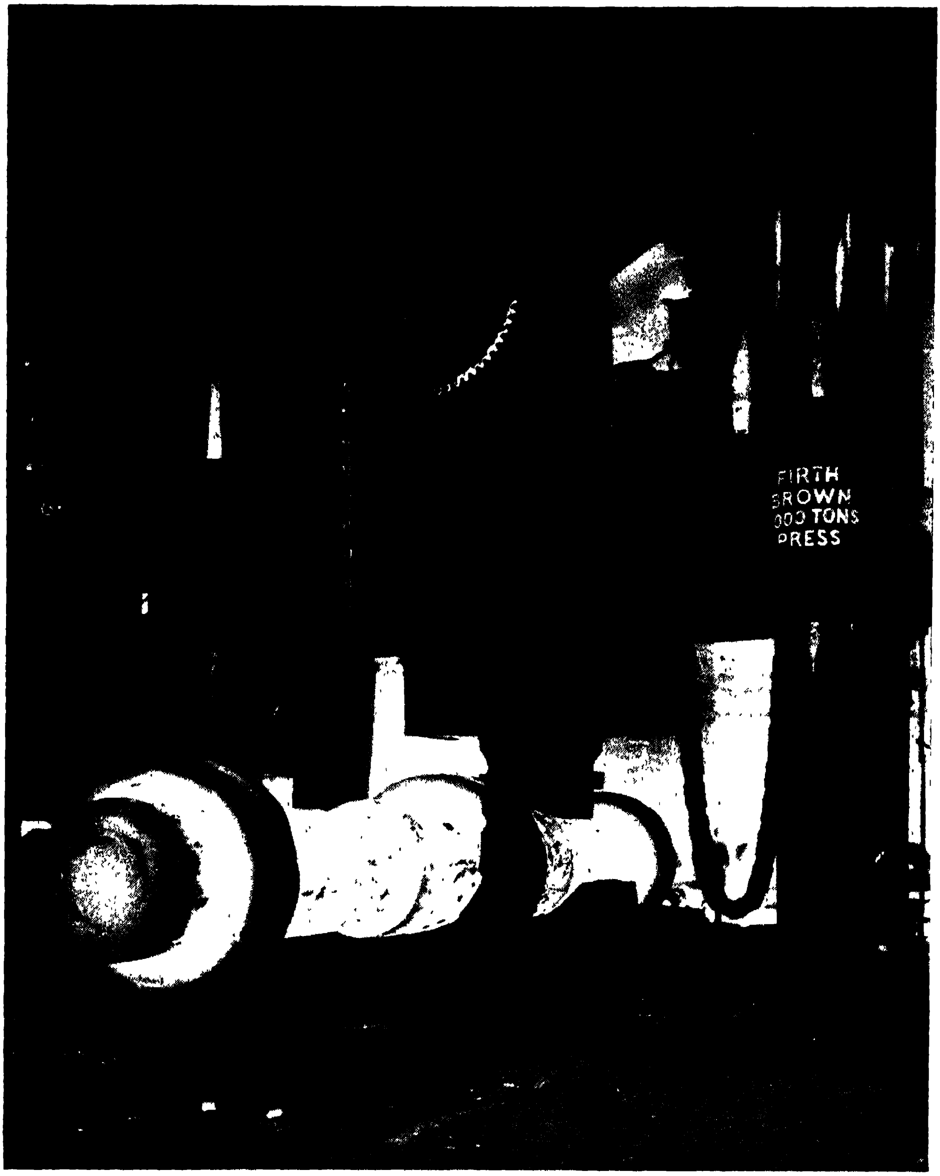
Pressed Bar. In *powder metallurgy*, a compact in the form of a bar.

Pressed Density. (See DENSITY.)

Pressing. (*a*) A particular type of drawing of sheet and strip metal, either cold or hot, by means of a press, fitted with the necessary holders, dies, punches, etc. Cups and many other shapes can thus be made, and the parts can be flanged, indented, embossed, etc. When an excessive amount of *cold work* is done, full or local *annealing* must be carried out. The risk of *season cracking* must also be avoided. (*b*) In *powder metallurgy*, the forming of a *compact* under pressure.

Pressing Crack. (See SLIP CRACK.)

Presspun Process of Dishing and Flanging. The machine employed in this process consists in the main of two heavy vertical columns of welded steel joined together at the top by deep horizontal girders. The girders carry a vertical hydraulic cylinder, the ram of which terminates in a circular platen opposed to a similar platen, or table, at the base of the machine. The platens are shaped to suit the contour of the head to be formed, and the heated plate is gripped tightly between them. The whole assembly of platens and work is then rotated round its vertical axis. At one side of the base, and near the edge of the bottom platen, is a vertical roller, the distance of which from the axis of the assembly is adjustable. In line with this is a second roller carried in a saddle mounted so that the roller can be moved from a position in which its axis is horizontal to one in which it is vertical. The saddle is traversed in a radial direction relative to the platen assembly by a motor drive



(*Reproduced by the courtesy of Thos Firth & John Brown Ltd.*)

Plate XII.—Large forging under 6000 tons press.

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through a worm reduction gear. Apart from the fact that its use eliminates the frequent reheatings necessary in the usual flanging methods, the Presspun process gives a much wider range of choice in design, since a series of expensive die blocks is not required. (E. 51.)

Pressure Casting. (See CENTRIFUGAL CASTING.)

Pressure Controlled Welding. (*Hydromatic Welding.*) A resistance welding process wherein each one of two or more electrodes in sequence goes through a complete welding cycle under the control of a hydraulic sequencing device synchronized with a welding current control device.

Pressure Die Casting. A die casting process in which the molten metal is forced into highly finished moulds under considerable pressure. It is used for producing in very large series parts with accurate dimensions, which need not be machined subsequently, or which have to be finished with a minimum of machining. The operation is carried out in die casting machines, of which there are two types: Injection, or *hot-chamber machines*, in which the melting apparatus is incorporated and the apparatus for injecting is arranged in the melting basin, and *cold-chamber machines* with separate melting furnaces and injecting apparatus. Both types of machines comprise a die actuating mechanism for opening and closing the dies.

Pressure Gas Welding. In this method the faces of the parts to be welded are heated, by an oxy-acetylene flame, until the metal becomes plastic but not molten, and the two ends are then joined together under pressure without the use of filler metal. This produces a flow of metal in the heated region, and thus welds together the faces of the work. (Z. 1.)

Pressure-Thermit Welding. A *thermit welding* process wherein coalescence is produced by heating with superheated liquid metal and slag resulting from the chemical reaction between iron oxide and aluminium, and by applying pressure. The liquid metal from the reaction is not used as filler metal. (A. 37.)

Pressure, Units of. In cgs. units, 1 *bar* $= 10^6$ dynes/sq. cm. 1 atmosphere = 760 mm. mercury at 0° C. at latitude 45° = 29·92 in. of mercury = 1·0133 bars = 14·7 lb./sq. in.

Pressure Welding. A group of welding processes in which pressure is applied whilst the surfaces to be joined are maintained in a plastic state. The process may be open butt, where the ends are heated from the end surface, or closed butt, where the ends are abutted before heating.

Prestressed Concrete. Concrete which has been compressed by stretching the reinforcing steel. By using high strength steel rods or wires, prestressing tension stresses up to 90 tons per sq. in. are being utilized. To gain maximum technical advantage from the prestressing techniques, pre-compression stresses in the concrete up to 1·35 tons per sq. in. are employed.

Prévost Theory of Exchange. The theory that a body at any temperature (apart from absolute zero) radiates, as well as receives heat. When the temperature of the body is in equilibrium with its surroundings, it radiates as much heat as it receives. Otherwise, the heat absorption is the difference between the heat received and the heat radiated.

Preweld Interval. In *spot, projection,* and *upset welding*, the time between the end of *squeeze time* and the start of weld time, or weld interval, during which the material is preheated. In *flash welding*, the time during which the material is preheated. (A. 37.)

Prials. (See PRILES.)

Priestley, Joseph. (1733–1804.) An English chemist who prepared various gases, notably oxygen.

Priles. (*Prials.*) Sheets which have been hot rolled, as the name implies, in a pack of three.

Primary. In regard to X-rays, those rays emitted directly from the anti-cathode in the X-ray tube.

Primary Crystals. The first *dendritic* crystals to form in an alloy during cooling below the *liquidus* temperature. (A. 26.)

Primary Metal. (See VIRGIN METAL.)

Prime Coat. (*Priming Coat.*) A first coat of paint originally applied to improve adherence of the succeeding coat but now frequently containing a corrosion inhibitor. (E. 10.)

Primes. Metal products such as sheet and plate of the highest quality and free from visible surface defects.

Priming. A carry-over of water with the steam from a boiler into the steam pipe. It is caused by a sudden generation of steam, due to too rapid boiling.

Priming Coat. (See PRIME COAT.)

Primitive Elastic Limit. This term has been defined as the value obtained for a material on first stressing from its virgin condition.

Principle Spectrum. (In *Revolving-Crystal* and *Oscillating-Crystal Patterns.*) (See ZERO SPECTRUM.)

Print Back. After drawing the *pattern*, the surface of the mould is dusted with

a carbonaceous material such as graphite, coal, etc., and the pattern replaced, rapped lightly into position, and again removed, leaving a smooth mould surface.

Probolog. An instrument designed for the inspection of the interior of non-magnetic tubes, e.g. of brass or austenitic steel. It embodies probes of different diameter to fit different diameter tubes; a mechanical probe puller; an electronic recorder with strip chart; and a gun to project the probe to the far end of the tube. The probe generates a magnetic field which penetrates the walls of the tube and induces eddy currents which react on the generating coils within the probe and modify their impedance. If the tube is unsound, the eddy currents are distorted and a deviated line appears on a chart. Localized corrosion can be readily detected by this means. (N. 6.)

Process Annealing. A treatment, commonly applied in the sheet and wire industries, in which an iron base alloy is heated to a temperature close to, but below, the lower limit of the *transformation range* and subsequently cooled. This process is applied for the purpose of softening for further *cold working*. It is sometimes known as *commercial annealing*.

Process Metallurgy. The science of obtaining metals from their ores. (A. 27.)

Producer Gas. (*Generator Gas, Power Gas, Siemen's Gas.*) A combustible gas obtained from solid fuel in a *gas producer*. It is usually made by passing air mixed with steam over red-hot carbon, e.g. coke, anthracite, or bituminous coal. The gas so obtained contains about 30% carbon monoxide, 10% hydrogen, 2% carbon dioxide, the remainder being principally nitrogen. Water gas and semi-water gas are modifications of producer gas.

Pro-Eutectoid. The constituent which separates out of a solid solution before the formation of the *eutectoid*. This, in the case of *hypereutectoid steels*, is *cementite*, and in *hypoeutectoid steels*, *ferrite*. (See Plates VII and VIII.)

Professional Engineers Appointments Bureau, 9 Victoria Street, London, S.W.1.

Proficorder. An instrument for recording waviness or other surface profiles. (A. 2.)

Profilometer. An instrument for measuring the roughness of surfaces, including internal and external surfaces, straight, tapered and circular. The equipment consists of three major parts: a tracer, which is moved manually or mechanically over the surface being measured; a portable amplimeter, which is connected to the tracer and includes a direct-reading micro inch meter; a motor-driven Pilotor or Mototrace, for operating the tracer where manual tracing is impractical.

Profiloscope. A simplified form of the *Profilometer* developed for use in the workshop. The instrument is based on a very simple principle in which a narrowly divergent light beam passes through the die on a tilting table, on to a screen placed below. When the die is horizontal a small bright circle of light is seen, outside which is a dark band, outside which again is a narrow band of light, all these being concentric one with another. The innermost circle is due to direct illumination through the die hole, and the outer, to internal reflection from the tapered region of the die. Should there be any changes in taper, they will immediately become evident as more concentric light circles, one for each change in taper, while a gradual change in taper causes a wider band of light. Any scoring will show as light radial lines radiating from the centre circle and the effect may be intensified by tilting the die. The profiloscope may also be used to measure the die angle by tilting the die, whereupon the outermost circle of light distorts to a heart-shaped image. (M. 111.)

Progressive Ageing. A process in which the temperature of the alloy is continuously increased during the *ageing* cycle. The temperature may be increased in steps or by any other progressive method. (Cf. INTERRUPTED AGEING.)

Progressive Block Sequence. A *block sequence* in which successive, but separate lengths, are welded progressively along the joint, either from one end to the other, or from the centre of the joint towards either end. (A. 37.)

Projection Welding. A *resistance welding* method similar to spot welding. The main difference is that the location and size of weld produced is determined by embossments or projections on the parts rather than by the shape or size of the electrode tip in contact with the surface. This process is used mainly to join small pieces together or to unite small pieces to larger parts. (W. 61.)

Prolongation. The term applied to an additional length which may be left on a forging. This prolongation is subsequently removed and may be used for the production of test pieces.

Promat. A rapid process for electroplating metallic objects with pure zinc, a coating of 12 to 15 μ being applied in 4 to 6 min.

Proof. The reproduction of a die impression. It may be obtained by clamping the dies together and pouring molten lead into the finish impression thus formed.

Proof Loading. A non-destructive inspection test which consists of the application of a load to a structure in such a manner that the resulting stresses are equal to or greater than the stresses to which the structure is subjected in service. (N. 10.)

Proof Resilience. (See RESILIENCE.)

Proof Stress. The stress (the load divided by the original area of cross-section of the test piece) which is just sufficient to produce, under load, a non-proportional elongation equal to a specified percentage of the original gauge length. In specifying or describing a proof stress, the non-proportional elongation should be quoted, e.g. 0·1% or 0·2% proof stress.

Proof Test. Any type of test to indicate that the material or structure is suitable for the purpose intended.

Proof Test for Creep. A tensile creep test carried out over a period of at least 48 hours at a temperature of 450° C. and with a stress of 8 tons/sq. in. It is specified that under these conditions the slope of the chord to the creep curve between 24th and 48th hour shall not exceed 50×10^{-6} strain per hour. (B. 100.)

Prop. An iron post used to support the bottom doors of the cupola. (A. 26.)

Propane. A gas, dimethyl methane ($CH_3CH_2CH_3$). It forms a useful fuel which can be compressed into cylinders and is utilized with oxygen in hot cutting of steel billets, etc.

Proportional Elastic Limit Stress. (*Limit of Proportionality.*) The stress (load divided by original area of cross-section of a test piece) at which the strain (elongation per unit of original gauge length) ceases to be proportional to the corresponding stress. It is usually assumed to coincide with the *elastic limit*.

Prot Method. A method of *fatigue testing*, using a progressively increasing load.

Protectatin. A method for protecting tinplate in which the plate is dipped into a hot phosphate-chromate solution containing a wetting agent, thus producing an oxide film which affords protection against sulphur staining and rusting in moist air. (C. 32.)

Protective Atmosphere. (See CONTROLLED ATMOSPHERE.)

Protectorite. A zinc-iron phosphate coating for application on iron and steel.

Proton. A fundamental unit of positive electricity having a positive charge but possessing a mass of the same order as the smallest atomic mass, which is 1836 times the mass of an *electron*.

Proton Microscope. An apparatus making possible magnifications of 600,000 or more, which has been built at College de France, Paris. The *electron microscope* magnification limit is stated to be 100,000 ×. (M. 64.)

Proust, Joseph Louis. (1754–1826.) A French chemist, who stated the law of constant composition.

Prover Test. A test used in the inspection of files, in which the file is required to attack a prover of at least 475 Brinell hardness, according to the type of file.

Proximate Analysis. (See ULTIMATE ANALYSIS.)

Prune Pack. A test for tinplate.

Prussian Blue. Ferric ferro-cyanide.

Prussic Acid. (HCN.) A solution of hydrocyanic acid, which is intensely poisonous.

P.S. Abbreviation for *proof stress*.

Pseudobinary (Quasi-binary) System. A three component or ternary alloy system in which an intermediate phase containing two of the metals in fixed proportions (that is, an intermetallic compound) acts as a single element. A certain vertical section through the ternary diagram is similar to a binary diagram. (A. 27.)

Pseudocarburizing. A term for *blank carburizing*.

Pseudocrystalline. Possessing regularities of structure that result in a diffraction pattern unlike that of a liquid or an amorphous solid, although true crystals are not present; for example, stretched rubber is pseudocrystalline. (A. 27.)

Pseudomorph. A crystal which has assumed a geometric form other than its own, the original mineral having been subjected to molecular displacement by another substance.

Pseudonitriding. A term for *blank nitriding*.

Pseudoscope. An instrument which exhibits objects in their proper relief reversed.

P.s.i. Pounds per square inch.

Psilomelane. (*Black Haematite, Black Iron Ore, Compact Black Manganese Ore.*) Hydrated manganese dioxide, in which part of the manganese is often replaced by barium or potassium. It is one of the most important manganese ores.

Pt. Chemical symbol for *platinum*.

P.T.G. Process. (See PREPARED TOWN GAS PROCESS.)

Pu. Chemical symbol for *plutonium*.

Puckering. The term applied to the corrugated or wave like formation in

that part of the wall of a drawn shape which has passed over the radius of the die.

Pucherite. ($Bi_2O_3.V_2O_5$.) A vanadium ore.

Puddled Bars. Flat bars of malleable iron produced in the *puddling process.*

Puddled Bloom or Billet. Approximately square section semi-finished wrought iron produced from puddling material.

Puddled Iron. Iron produced by the *puddling process.*

Puddled Steel. Steel made from pig iron by the *puddling process.*

Puddler's Candles. The jets of blue flame produced when carbon monoxide is released from the puddled balls during the production of wrought iron in the *puddling process.*

Puddlers' Mine. A variety of haematite used in the fettling of puddling furnaces.

Puddlers' Tap Cinder. The slag from the puddling furnace, consisting of ferrous silicate containing varying amounts of ferrous and ferric oxides.

Puddling. A process, invented about 1780 and still in use, for the production of wrought iron. Pig iron is melted on the hearth of a small *reverberatory furnace* at a temperature above the *melting point* of pig iron but below that of wrought iron. In *dry puddling*, the furnace is lined with siliceous materials, and white iron only is refined, but in *wet puddling*, the lining consists of iron oxide and both the lining and the oxides added during the process are known as *fettling*. The process is carried out in an oxidizing atmosphere and the silicon, manganese and part of the phosphorus is oxidized during the melting down and in the interval preceding the boil. The boil removes still more phosphorus and the greater part of the carbon. During the final stage, the *melting point* rises and the metal becomes pasty, i.e. it is "*coming to nature*". The iron is then gathered together into balls which are taken to the hammer and worked into blooms to expel as much *slag* as possible, after which the blooms are rolled into *puddled bars*.

Puffed Compact. The term, as used in *powder metallurgy*, refers to a compact expanded by internal gas pressure. (G. 30.)

Pug Mill. A mill for grinding and mixing the constituents of concrete, mortar, etc. Mills of this type may be used in conjunction with sinter plants or blast furnace dust catchers.

Pugh Type Ladle. A refractory lined iron vessel for receiving the iron from the blast furnace. It is cigar-like in shape and has an opening at the top to receive the iron. To empty, it is rotated about its longitudinal axis. Such ladles vary in capacity up to 150 tons and may function as *mixers*.

Pull Cracks. (*Restriction Cracks, Pulls.*) (*a*) Cracks caused in a casting by thermal contraction when two portions become anchored as a result of an irregular shape. (See HOT TEAR.) (*b*) A transverse crack in the face of an ingot due to the same cause, i.e. restriction to free contraction during freezing.

Pull Down. A term applied in the foundry to a *buckle* in the *cope* sometimes severe enough to cause a *scab.* (A. 26.)

Pull Over Gear. A mechanical device used to transfer or pull over a rolled piece laterally from one stand to another during the rolling operation.

Pull Over Mill. (See ROLLING MILLS.)

Pulled Bars. Square and thin flat sectioned bars with ruptures at the corners.

Pulled Strip. Strip of irregular width due to excessive tension during hot rolling.

Pulling-In Dog. A device used on a wire drawing machine to grip the end of the wire when threading up.

Pulls. (See PULL CRACKS.)

Pulpit. A bridge above a *rolling mill* from which operations are controlled.

Pulsation Welding. (*Multiple Impulse Welding.*) A *spot welding* process wherein the welding current is interrupted one or more times without release of pressure or change in the position of the electrodes.

Pulsation Weld Timer. (See MULTIPLE-IMPULSE WELD TIMER.)

Pulse Annealing. A method which involves direct heating of a very small sample to a chosen annealing temperature for a short period, followed by rapid cooling to a fixed temperature for an in-place physical property measurement. This cycle is repeated to obtain data for any desired time-temperature history. (P. 6.)

Pulse Polarizer. An instrument used in studying *electrochemical corrosion* phenomena. The metal specimen under test is made highly anodic or cathodic over a very brief time interval, with the result that the surface of the metal becomes highly polarized. The extent of the polarization phenomenon depends upon the metal and the environment surrounding it. The process of depolarization begins immediately after the polarization products have accumulated on the metal surface and tends to return the electrode to the normal value. The potential of the test electrode is referred to a reference electrode such as a

calomel half-cell which is also immersed in the solution containing the test electrode. The potential difference existing between these electrodes is detected on an electronic voltmeter circuit, amplified and applied to a continuously-balanced high-speed recorder. The recorder then traces out the potential of the test electrode as a function of time. It is suggested that inhibitors be classified by their *McDonald numbers* which are defined as the logarithm of the ratio of uninhibited weight-loss to inhibited weight-loss. (M. 77.)

Pulse Testing. (See SONISCOPE.)

Pulverization. (*Comminution.*) The reduction of matter to powder by mechanical means; a specific type of disintegration.

Pumping. The action of feeding molten metal to a casting from a *feeding head* by forcing it with a rod which is moved up and down, in the feeding head.

Punch. (*a*) A steel tool for making holes in metal by shearing out a circular wad under pressure, the work being supported on a *die*, the hole in which is slightly larger than the diameter of the punch. (*b*) A term frequently applied to a machine designed to deliver highly concentrated mechanical pressure to a punching tool. (*c*) In *powder metallurgy*, the lower punch is the lower member of a die assembly which forms the bottom of the die cavity. It may or may not move in relation to the die. The upper punch is the member of a die assembly which moves into the die to transmit pressure to the powder contained in the die cavity. A *stripper punch* is a punch, which, in addition to forming the top or bottom of the die cavity, later moves further into the die to eject the *compact*.

Puncheon. A liquid measure of 84 gallons.

Punching. The operation of forcing a punch into a hot piece of steel for the purpose of forming a cavity. In engineering, the term punching is used when the hole extends through the entire section, whilst *cupping* refers to the making of a blind cavity without removal of metal. *Piercing* usually refers to the making of a blind cavity, but the term is not strictly limited to this, as for example, in the piercing of ingots when the hole is made right through the ingot. (See also TREPANNING.)

Pups. (*Soaps.*) Firebricks of a certain standard size.

Pure Oxides. A group of refractories. These include: alumina (2050° C.), magnesia (2800° C.), thoria (3050° C.), zirconia (2700° C.), beryllia (2500° C.) and ceria (2800° C.). The figures in parentheses represent their melting points.

Purging. The elimination of air and other undesirable gases from furnaces or heating boxes, as, for example, prior to *bright annealing*. When using cracked ammonia or hydrogen, *pre-purging* with an inert gas such as nitrogen or completely combusted town gas is essential.

Purnell Quenching Process. The basic features of this process are: first, the uniformity of the quench which is obtained by the use of propeller agitators. Second, is increased speed in quenching which produces a more suitable microstructure. The third feature is accurate timing of the quench. The time the work is in the quench bath is precisely regulated and, once set for a specific article, is adhered to closely. This time may be long enough to form a certain amount of *martensite* or only long enough to form *bainite*. The fourth point is the immediate tempering. The quenched work is tempered as soon as possible, without allowing it to cool any more than is absolutely necessary. This helps to produce greater toughness and less warpage or cracking, and eliminates any possibility of developing minute incipient internal ruptures which may encourage subsequent failure of the part. (P.52.)

Puron. High purity iron.

Purple Ore. (See BLUE BILLY.)

Push Bench. Equipment used for drawing heavy-gauge tubes by the *push bench process*.

Push Bench Process. A process for making seamless steel tubes in which a billet of suitable shape, at forging temperature, is first formed into a thick hollow cylinder, generally with a solid end; then placed on a long mandrel bar and pushed through a series of successively decreasing dies or rolls.

Push Fit. A term used in engineering to denote a close fit.

Push Up. An indentation in a casting surface due to displacement of sand in the mould. (A. 26.)

Push Welding. (See POKE WELDING.)

P.V.C. Mould. A polyvinyl chloride mould.

P.V. Hardenability Test. A quenching test suitable for the determination of the hardenability of shallow-hardening steels which require cooling rates faster than 45° C. per sec. at 704° C. in order that the microstructure retains 50% of martensite. The specimen for this test is formed from a 1¼ to 1½ in. diam. round bar by making two mutually perpendicular cuts at 45° to the axis to give a chisel edge. The specimen is

quenched in a special fixture by causing a jet of water to impinge on the chisel edge; it is sectioned parallel to the axis, hardness measurements being made on the cut faces. (S. 57.)

Pyknometer. (*Sprengel Tube.*) An instrument for determining the specific gravity of a liquid. It consists of a wide glass tube into which are fused two capillary tubes. These are drawn out to tapering ends which are ground to fit small glass cups which serve to prevent volatilization of the liquid under test.

Pylumin Process. A process similar to the *M.B.V. process.*

Pyramid Hardness. (*V.P.N.*) (See VICKERS PYRAMID DIAMOND HARDNESS.)

Pyrites. Sulphur ores of iron and copper. Iron pyrites is FeS_2; copper pyrites (*Fool's Gold*) is $CuFeS_2$.

Pyrobelonite. ($4PbO.7MnO.2V_2O_5.3H_2O$.) A vanadium ore.

Pyrobraze. Contact *soldering* equipment which uses a carbon electrode in place of a bit and the heat is generated directly at the point on the work where it is required. (A. 13.)

Pyrochlore. A potentially important mineral composed largely of oxides of niobium and tantalum. Deposits have been reported from a number of places in Nigeria and Eastern and Central Africa but a deposit more recently discovered in Northern Rhodesia yields samples in which the combined oxides amount to over 73%, nearly 10% more than any other known pyrochlore.

Pyrochroite. A mineral found in Sweden and consisting essentially of hydrated manganese oxide.

Pyro-Electro Hardness Tester. A direct-reading universal hardness testing machine which is calibrated for three balls, $\frac{1}{16}$ in., $\frac{1}{8}$ in., and 5 mm.; also for a diamond penetrator. The load is applied by a hand-operated crank. The standard machine has a vertical capacity of 8 in.; load capacities of 60 kg., 100 kg., and 150 kg., with no change in minor load. Tests on very thin stock, say at 15 kg. or conversely, at 750 kg., require a special type of indenter.

Pyrofax. A liquefied hydrocarbon gas composed almost entirely of *propane*. It has been used in *gas carburizing.* (P. 18.)

Pyrolock. A protective quick-drying coating which is applied to metal by spraying. It is claimed that this treatment confers to the metal considerable resistance to heat.

Pyrolusite. Natural manganese dioxide, MnO_2, the chief ore of *manganese.*

Pyrolytic Plating. Coating by thermal decomposition of the *carbonyl* of the metal to be applied, e.g. molybdenum or tungsten. (L. 5.)

Pyrometer. An instrument for measuring temperatures. The main types are: (1) *Resistance pyrometers*, making use of the property of change of resistance of a substance with temperature. (2) *Thermoelectric pyrometers*, using the principle of the *thermocouple.* (3) *Optical pyrometers*, in which the temperature is obtained by comparison of colour or brilliance of the hot body with a known value. (4) *Radiation pyrometers*, based on the measurement of heat radiation, and *photoelectric cell* pyrometers, using the light radiation from a hot body. (See BROWN-FIRTH PHOTOELECTRIC PYROMETER.)

Pyrometer Tube. A tube of a heat resistant alloy or refractory material, frequently silica, sealed at one end, which contains a *thermocouple* for the measurement of temperatures.

Pyrometric Cone Equivalent. (*P.C.E.*) A value used in the determination of refractoriness, in which the refractory under test, in the form of a *cone*, is heated together, and under precisely similar conditions, with a series of standard cones of known melting points. The P.C.E. value of the refractory under test is taken as that of the standard cone having the nearest melting point. The melting point (i.e. *deformation-*, *fusion-*, or *softening-point*) of a cone is taken as the temperature at which the tip of the cone is bent over to the level of the base.

Pyrometric Cones. Small, pyramid-shaped pieces whose composition is so adjusted to melt at a definite temperature under standard conditions. (e.g. SEGER CONES.)

Pyrometry. The art and science of temperature measurement.

Pyromike. A small *optical pyrometer.* In use, the instrument is sighted on to the object through a hole in the furnace door and a screw is turned until the object becomes invisible owing to the matching of the colour. The temperature is then read off on the scale at the side of the instrument.

Pyrophoric Alloys. Alloys, usually of iron and cerium, which emit sparks when submitted to friction. Such alloys are used for cigarette lighters.

Pyro-Total Radiation Pyrometer. In this *pyrometer*, the radiant heat is focused, by means of a quartz lens, on to a *thermocouple* enclosed in an evacuated bulb. (G. 10.)

Pyrrhotine. (See PYRRHOTITE.)

Pyrrhotite. (*Pyrrhotine.*) (*Magnetic Pyrites.*) A magnetic sulphide of iron in which nickel is often present.

Pythagoras. (*a*) A Greek philosopher and mathematician. (*b*) A highly refractory material similar to *alundum*. It is claimed to be impervious to gases up to 1500° C. and is very resistant to sudden changes of temperature. It is used for the production of thermo-electric pyrometer tubes, tubes for vacuum work at high temperature; crucibles, combustion boats and furnace linings.

PZ3 Tester. A hardness testing instrument of the Brinell type which is claimed to be the lightest machine capable of applying the standard 3000 kg. load. It weighs 10 kg., the load being measured on a dial actuated by the elastic deformation of the frame. (H. 9.)

P.Z.J. Hardness Tester. A German machine designed for the measurement of the hardness of the internal surfaces of bores or cylinders. The indenter is a ball of 5 mm. diam. under a load of 750 kg. As the impressions obtained cannot, of course, be measured by means of a microscope, the instrument is provided with a dial impression depth gauge and the readings thus obtained are converted into Brinell hardness numbers. (H. 9.)

Q

Q-Value. (See QUALITY VALUE.)

Quadrilateral. Plane figure bounded by four straight lines.

Qualitative Analysis. The determination by chemical methods of the identity of an element or of the constituents of a mixture without regard to the percentage composition.

Qualities. Distinctive grades of steel and iron, e.g. *electric, acid* or *basic* steels or as regards wrought iron, "Crown", "Cable", "Best", "Marked Bars", "Yorkshire Iron", and other grades made to British Standard specifications.

Quality Value. (*a*) A value designed for comparing the properties of a steel with those of a standard steel in order to determine its relative merits. The figure used for the comparison is termed the *figure of merit, merit number*, or quality figure. The formulae are based on the assumption that, under the same conditions the ductility decreases as the strength increases, and vice versa. This assumption is only approximately true, and applies only within certain ranges, but the values obtained are sufficiently accurate for most purposes. The steel possessing the highest combination of strength and ductility is, therefore, assumed to have the highest quality value. Formula: $M = T + E$, when M = figure of merit; T = tensile strength in tons per sq. in., and E = elongation in per cent, for specimens of identical shape. The relationship $\frac{T}{E}$ is used in certain U.S.A. specifications. (*b*) A *figure of merit* commonly used to designate the ratio of the inductive reactance to the effective resistance of electrical cores made from iron and other powders.

Quantitative Analysis. The precise determination by chemical methods of the percentage composition of a substance or mixture.

Quantometer. An electronically operated form of direct reading spectrograph. (E. 31.)

Quantum. A finite unit or bundle of radiant energy emitted when an electron moves to the next inner orbit or energy level of an atom.

Quantum Numbers. Numbers which define the various elliptical orbits in which *electrons* can revolve round the *nucleus*.

Quantum Theory. The hypothesis, accounting for the stability of the atom and other phenomena, that in radiation the energy of electrons is discharged not continuously but in discrete amounts or quanta.

Quarto. (*4to.*) Size given by folding a sheet of paper twice. (See BOOK SIZES.)

Quarto Mill. A rolling mill used in the manufacture of seamless steel tubes. In the quarto machine, each stand or roll head contains four rolls operating on the tube, and each stand is driven from an independent synchronized motor. Since in the *duo mill*, the peripheral speed at the top of the roll is greater than that at the bottom of the groove, there is a slight inequality in the thickness of the shell of the finished product. In the quarto machine, the shallower groove obviates this difference in peripheral speeds and the tube, therefore, has a more uniform wall thickness. (B. 54.)

Quartz. A mineral consisting of crystalline silica with a hardness of 7 on *Mohs' scale*.

Quartz Conglomerate. A rock made of pebbles of quartz with sand. The pebbles are sometimes of jasper and chalcedony, and make a beautiful stone when polished.

Quartzyte. A rock consisting of very firmly compacted quartz grains.

Quasi-Arc Welding. A system of arc welding in which covered iron electrodes are used, the covering consisting of

asbestos yarn impregnated with a fluxing compound. The covering protects the deposited metal from oxidation.

Quasi-Bessemerizing. A process for making ingot moulds of haematite iron which consists of blowing a small amount of air into the molten iron as it cools in the sand mould. The apparatus consists of tubes and fittings for supplying a regulated flow of compressed air at 15 lb. per sq. in. through a ⅛ in. steel tube introduced into the highest part of the mould near a riser head. The air passes into the molten metal and emerges accompanied by impurities contained in the iron. The air is blown in irregular pulses which cause large masses of iron to beat upon the walls of the sand mould; this vibration can be both heard and felt. The process is claimed to reduce the amount of free graphite present, and thereby to reduce the tendency of the ingot mould to fail by crazy cracking and to increase the resistance to failure by major cracking. (W. 56.)

Quasi Binary. (See PSEUDOBINARY.)

Quaternary. Consisting of four components.

Quench. (See QUENCHING.)

Quench Ageing. A characteristic of low carbon steels and irons which when quenched from a temperature just below the Ac_1 change point, exhibit a tendency to increase in hardness, when allowed to age at room temperature; this increase is progressive up to a period of time at which a maximum value is reached. There are marked differences between quench ageing and *strain ageing*, for example, in quench ageing the period for obtaining the maximum effect when ageing at room temperature is in the region of four weeks and this process cannot be accelerated by raising the temperature. (See also AGEING.) (P. 29.)

Quench and Fracture Test. A method of determining the *grain size* and *hardenability* of steel in which normalized sections are heated above the Ac_3 point, quenched at intervals of 30° C., and compared with standard fractures. The method is also used in the examination of steels for freedom from defects.

Quench Bend Test. (*Temper Bend Test.*) A test in which the steel test piece is raised to a cherry red heat and water quenched before submitting to a *bend test*.

Quench Cracking Susceptibility Test. A method which consists of determining the minimum depth of notch necessary to cause a quench crack in a specimen consisting of a notched hollow disc having an outside diameter of 6·5 in., an inside diameter of 2·75 in., and a thickness of 0·5 in. The disc contains one notch having an angle of 30 degrees and a root radius of 0·010 in. (W. 35.)

Quench Hardening. The process of hardening a ferrous alloy of suitable composition by heating within or above the *transformation range* and cooling at a rate sufficient to increase the hardness substantially. The process usually involves the formation of *martensite*. (A. 26.)

Quench Tempering. A method of quenching steel from a suitable temperature in a bath, held at a tempering temperature. The steel is immersed in the bath until it attains bath temperature. It is then withdrawn and air cooled.

Quenching. Rapid cooling from an elevated temperature, generally carried out by immersion in a liquid bath of oil or water. Quenching oils consist of two main classes, fatty oils and mineral base oils. The latter type include the straight mineral oils, compound and additive oils. Other quenching fluids include brine, and dilute caustic soda solution, the latter two media being used to give a more drastic quench than water. Salt baths or fused metals are used for special heat treatments such as *austempering*. The usual effect of quenching is to confer hardness as the sudden abstraction of heat suppresses the phase transformation of austenite to pearlite, forming instead the harder constituents *bainite* or *martensite*. The austenitic steels, such as the corrosion-resistant steels of the 18% chromium, 8% nickel type, and the 14% manganese steels, are not hardened by quenching.

Quenching Crack. (*Hardening Crack.*) A fracture resulting from thermal stresses induced during rapid cooling.

Questal Bentonite. A colloidal bond which, when added to moulding sands in amounts up to 3%, increases porosity and strength (green and dry), and reduces the amount of water needed. (W. 60.)

Quick Immersion Pyrometer. (See SCHOFIELD-GRACE IMMERSION PYROMETER.)

Quicklime. Calcium oxide, CaO. It combines with water, with evolution of heat, to give slaked lime, calcium hydroxide, $Ca(OH)_2$, the strong exothermic reaction causing the lumps of quicklime to break into fragments.

Quick Silver. *Mercury.*

Quicking. The deposition of a thin film of mercury on metals, e.g. copper alloys, by immersion, prior to plating

in a solution consisting of mercuric chloride dissolved in sodium cyanide.

Quinary Alloy. An alloy containing five elements.

Quinhydrone Electrode. A device consisting of a bright platinum electrode immersed in a saturated quinhydrone solution used for the measurement of *pH values* in neutral or acid solutions.

Quinquevalent. Having a *valency* of five.

Quintal. 220·5 pounds; 100 kilograms; 100,000 grams.

R

R. Abbreviation for radioactive mineral.

r. Abbreviation for radius.

°R. (*a*) Abbreviation for *Rankine scale*. (*b*) Abbreviation for *Réamur scale*.

R Values. (See FLEX-TESTER.)

Ra. Chemical symbol for *radium*.

Rabble. A long iron rod used for stirring the molten steel bath in the *electric arc-*, *open hearth-* or *puddling-furnace*.

Rabbling. The operation of stirring the molten steel bath by means of a *rabble*.

Race. The inner or outer steel rings of a *ball-* or *roller-bearing*.

Rack Drawn. (See BENCH DRAWN.)

Radial Test. (See TRANSVERSE TEST.)

Radiamatic Pyrometer. A pyrometer for measuring temperatures in the 30° to 300° C. range. It has three components, the receiving instrument containing a group of small thermocouples on which a lens focuses the radiation, a reference junction temperature controller, and an electronic potentiometer. The instrument has a rapid response and can be used for measuring the temperature of moving objects. (H. 49.)

Radian. An angle at the centre of a circle subtended by an arc whose length is equal to the radius.

Radiant Cup. A refractory cup-shaped burner for gas-fired heat treatment furnaces, in which a gas-air mixture is fed to radial slots at the base; the shape and position of the slots being such that the mixture burns in contact with the surface of the refractory cup, which is shaped to follow the natural sweep of the flames. The cup surface thus becomes highly incandescent so that it constitutes an effective source of radiant energy, accelerates the gas-air reaction by acting as a catalyst and causes a very high rate of heat liberation in a small space whilst ensuring complete combustion. (H. 48.)

Radiant Energy. Energy consisting of electromagnetic waves, such as light or heat.

Radiant Heat. Heat communicated to a body by *radiation* and transmitted by electromagnetic waves.

Radiant Intensity. The *radiant power* per unit solid angle in any direction from a source.

Radiant Power. The amount of energy emitted per second.

Radiate Structure. A characteristic of pure metals and certain eutectics in which crystallization has proceeded from the centre outwards.

Radiation. (*a*) Energy emitted in the form of electromagnetic waves. These include, in order of increasing wavelength, cosmic, gamma, X-rays, ultraviolet, visible and infra-red radiation, and radio waves. (See BLACK-BODY.) (*b*) A process by which heat may be transferred from a source to a receiver without heating of the intervening medium or without the existence of a material medium, e.g. heat received by the earth from the sun.

Radiation Loss. The heat loss by *radiation* as, for example, the heat radiated from the outer surface of a furnace.

Radiation Pyrometer. An instrument for determining the temperature of a distant source of heat. The heat radiated from a hot body is focused either by lens or mirror on to a *thermocouple* or a *thermopile*, thus giving rise to an *e.m.f.* proportional to the temperature of the hot body. Optical filters may be employed to render the pyrometer responsive to selected wavelengths, but in all cases other than *black body* conditions appropriate *emissivity* corrections are required for accurate measurement. (See also TOTAL RADIATION PYROMETER.)

Radical. A group of elements, having an unsatisfied *valence*, acting as a single element in a chemical reaction, but normally incapable of separate existence.

Radio Frequency Induction Furnace. A furnace developed for the melting of alloys in small quantities, e.g. 5 to 20 lb. In a typical furnace the frequency is of the order of 600 kcs. per second. No elaborate foundations are necessary, and smaller units, if required, may be portable.

Radioactive Isotopes. Varieties of an element possessing the same chemical characteristics, but emitting detectable radiations by means of which they can be identified and traced. Of the various radioisotopes available as by-products of the atomic energy programme, some emit beta rays, some the more penetrating gamma rays, while yet others emit both. There are two general fields of industrial application, viz., as tracers and radioactive sources. A tracer is

an element tagged with radioactivity for identification purposes. This tag follows the element through complicated chemical and physical processes in such applications as chemical analysis, the evaluation of industrial cleaning methods, wear measurements in engines, and investigations of the nature of surface friction. Radioactive iron and calcium have been used to study reactions between molten iron and slags, while in physical metallurgy, five different isotopes have been used in studies on diffusion in metals, oxidation and scaling, and in attempting to study structure or segregation by exposure of photographic film to radioactive alloys. Certain radioactive isotopes now available (e.g. iridium 192, tantalum 182, cobalt 60) can be used as a source of gamma-rays for *non-destructive testing*. They occupy much smaller volume than the equivalent quantity of radium bromide and thus give radiographs with better definition, while they have the advantage over *radon* of lower cost and much longer life. They are particularly useful for testing thick sections (e.g. over 60 mm. of steel) or components having sections of widely differing thickness, which are outside the range suitable for X-ray testing.

Radioactive Metals. The naturally occurring radioactive metals consist of a group of metals with high atomic weights and with atomic nuclei that decompose slowly, giving off continual radiations of positively charged alpha particles, which are relatively slow; negatively charged beta particles, which are faster and lighter; and gamma rays. The gamma rays are similar to X-rays but are more penetrating and are used for the radiography of very thick sections. It should be noted that bombardment by *neutrons* can make any metal radioactive.

Radioactivity. The spontaneous disintegration of the radioactive metals.

Radiochemical Centre, Amersham, Bucks. A branch of the Atomic Energy Research Establishment, which processes and distributes radioactive materials. Three main groups of product are available: chemical compounds containing radioactive isotopes, beta- and gamma-ray sources for medical and industrial use, and neutron sources.

Radiogram. (See RADIOGRAPH.)

Radiograph. (*Radiogram.*) (*Skiograph.*) A processed photographic film produced by passing *X-rays* or *gamma-rays* through an object on to a film, thereby recording the differential absorption of the rays by the object. The radiograph is a shadow picture, dark regions representing the more penetrable sections of an object, whilst the lighter regions correspond to the more opaque. (E. 87.)

Radiographic Contrast. The difference in blackening on a radiograph resulting from variations in the thickness or density of the material under examination. (C. 34.)

Radiographic Density. The degree of blackening of a *radiograph*. (C. 34.)

Radiographic Relief Printing. In this method, after the initial normal exposure, a contact positive film is made from the original radiograph. The two films are then placed together, in the printing frame in such a way as to take advantage of the parallax effect or rather, the slight displacement of it. Printing paper is placed over them and an exposure made. The exposure must be by trial and error according to the density of the combined double effect of the radiograph and the positive contact. (W. 39.)

Radiographic Sensitivity. (*a*) The ability of a given radiographic technique to reveal discontinuities or changes in density in the material under inspection. (*b*) The clarity of the X-ray image on the finished radiograph. (C. 34.)

Radiography. A non-destructive method for internal examination of a metallic body exposed to a beam of *X-ray* or *gamma* radiation. Differences in thickness, density or absorption caused by internal defects or *inclusions* are apparent in the shadow image, either on a fluorescent screen or on a photographic film placed behind the object. Thicknesses of steel up to 14 in. can be satisfactorily inspected by X-rays produced by voltages of 10 megavolts, which voltage seems to be the optimum. Radiographs have been taken on as much as 22 in. of steel.

Radiology. That branch of science which deals with the examination of a body by means of X-rays, with the interpretation of *radiographs*.

Radiomicrography. See MICRORADIOGRAPHY.)

Radium. (*Ra.*) *Atomic weight* 226·05. *Melting point* 700° C. A brilliantly white metal which turns black when exposed to the air owing to the formation of a nitride. It readily attacks quartz or glass and rapidly decomposes water, forming a hydroxide as with the alkali metals. Radium is widely used in therapy, but its employment for luminous paint for industrial dials now greatly exceeds its medical use. Radium may also be used in place of X-rays for the examination of metal for flaws.

Radivection. The use of combined radiation and convection heating for reheating

furnaces designed for use at temperatures up to about 950° C.

Radon. (*Rn.*) (*Niton.*) *Atomic weight* 222. It is an emanation of radium, and the heaviest of the inert gases. Radon, being radioactive, may be used to examine the opaque materials, such as metals, for the detection of defects, viz.: internal flaws, cracks and porosity. These defects, when irradiated, cast shadows which may be recorded on a photographic plate, the shadows being caused by differential adsorption of the radiation within the specimen. Radon has been used successfully in the examination of steel structures of up to 9 in. in thickness. (P.50.)

R.A.E. Royal Aircraft Establishment, Farnborough.

Rag. (*a*) Excess metal squeezed out in *pressure welding*. (*b*) A small notch or unfilled section of a forging.

Ragged Rolls. Rolls having a roughened surface. (See RAGGING.)

Ragging. A series of grooves, usually horizontal, made in the surface of a roll in order to assist the roll to bite the steel and to prevent skidding between the roll and the work. Ragging is usually found in roughing and forming passes.

Ragging Marks. Rolling defects which appear as protrusions on the surface of steel.

Rail. A straight hot rolled bar of special section used to provide a track for flanged wheel rolling stock.

Rail Test. A test for the ductility of rails in which a tup weighing one ton is allowed to drop from varying heights on to the middle of a rail section mounted on supports 3 ft. apart.

Rainbow Plating. This process of electroplating is so called from the banded colour arrangement obtained. One solution contains ammonium molybdate 40 and sodium cyanide 2 g./litre, and is operated at 70° to 90° C. Several solutions which deposit nickel and copper are also recommended. Variation in thickness of the deposit is necessary to produce the widest range of colours; this is obtained by using two different lengths of platinum wire anode and moving them over the face of the cathode. The brightest effects are obtained on polished metal surfaces, and designs may be produced by masking. Sodium plumbite solutions give similar rainbow effects when the metal is made the anode, lead being simultaneously deposited on the platinum-wire cathode.

Raisings. Sections of *flasks*, without bars, used together with flasks to give various depths of flasks desired. (A. 26.)

Rake. The angle of inclination given to the faces of cutting tools to obtain the required cutting angle: *Side Top Rake* (*Cutting Edge Side Rake*). The angle between the base and the face, measured in a plane at right angles to the plan approach angle. *Front Top Rake* (*Cutting Edge Back Rake*). The angle between the base and the face, measured in a plane parallel to the plan approach angle. *Angles of Rake* are positive if the face slopes downwards from either side or front cutting edge or other face edge, and negative if the face slopes upwards. *Maximum Rake*. The maximum angle between the base and the face measured in a plane perpendicular to the base. *Maximum Rake Plan Angle*. The angle between a line parallel to the side of the shank and the direction of maximum rake, measured in a plane parallel to the base. *Clearance Angle*. The angle between a line at right angles to the base and that portion of the flank immediately below any cutting edge or other face edge measured at right angles to the edge. *Secondary Clearance Angle*. The angle between a line at right angles to the base and that portion of the flank situated below the clearance angle measured at right angles to the cutting edge. *Wedge Angle*. The included angle between the face and that portion of the flank forming the clearance angles, measured at right angles to the cutting edge. *Plan Approach Angle*. The angle between the side cutting edge and the side of the shank, measured in a plane parallel to the base. In the case of a bent tool this angle is measured from the straight side of the shank. *Plan Trail Angle*. The angle between the nose or front cutting edge and a line at right angles to the side of the shank, measured in a plane parallel to the base. In the case of a bent tool this angle is measured from the straight side of the shank. *Included Plan Angle*. The included angle between the front cutting edge (or trail edge) and the side cutting edge, measured in a plane parallel to the base. (F. 16.)

Ram. (*a*) To pack sand in a mould. (*b*) To consolidate the hearth of an *open hearth furnace*. (*c*) The moving part of a drop hammer or a press to which one of the dies is fastened. (*d*) In pressure welding, the part which transmits the force to the electrode.

Ram Off. (See RAMAWAY.)

Ramaway. (*Ram Off.*) A casting defect resulting from a section of the mould being forced away from the pattern by ramming sand after it has conformed to the contour of the pattern. (A. 26.)

Rammability. The ability of a moulding material to ram to a firm mould surface capable of supporting a load.

Rammer. A tool used for consolidating the sand in the mould. A *peg rammer* is used for forcing sand into corners. A *flat rammer* is used to pack the whole mass of sand in the mould, but in plain moulds the peg rammer may be replaced by the *ball rammer.* Hand rammers are usually made of wood, and the larger sizes of iron.

Ram's Horn Test. A drifting and bending test applied to wrought iron. Specimens of the bars, as rolled, are punched at 815° to 870° C. with a punch one-third of the diameter or width of the bar and at a distance from the end of the bar equal to 1½ times the diameter or width of the bar. The hole is then drifted out to 1½ times the diameter or width of the bar. The end of the bar is then split up to the hole and the ends are turned back. The specimen is required to undergo this test without fracture. (B. 100.)

Ramsay, Sir William. (1852–1916.) An English chemist who discovered several of the inert gases; he is chiefly remembered for his work on radium emanation.

Random Orientation. The condition existing when the arrangement of the crystal grains is irregular, i.e. when the principle axes of the grains do not conform or tend to conform to any particular direction.

Random Sequence. (See WANDERING SEQUENCE.)

Randupson Process. A system of moulding in which the moulds are made of a mixture of silica sand and cement with water added. (L. 46.)

Range. The term used in connection with chemical or physical properties refers to the difference between the upper and lower limits of the specification, e.g., in a 3% nickel steel the range is frequently given as not less than 2·75% and not more than 3·25%.

Range of Proportionality. (*Elastic Range.*) In a tensile test, that range of loading in which the strain produced is directly proportional to the applied stress. The *law of proportionality* between the stress and strain in this range is known as *Hooke's law.*

Range of Stress. The range between the upper and lower limit of a cycle of stress such as is applied in a *fatigue test.* The midpoint of the range is the *mean stress.*

Rankine Scale. A temperature scale in which the zero is *absolute zero* and the size of the degrees is that of the Fahrenheit scale, i.e. the temperatures in degrees Rankine are equivalent to degrees Fahrenheit plus 459·6.

Rankine, William John Macquorn. (1820–72.) A British physicist, and one of the founders of the science of thermodynamics.

Raoult's Law. The fractional decrease of vapour pressure of a solution, as compared with vapour pressure of pure solvent, is equal to the mol fraction of solute in the solution.

Rapid Tool Steel. A name, now seldom used, for *high speed steel.*

Rapideep. A carburizing compound of the sodium cyanide type which, it is claimed, enables very close control over the case hardening operation and, if necessary, a considerable depth of carburization to be attained. The depth of case may be accurately estimated on the basis of the time of immersion in the carburizing bath and the strength of the cyanide bath. (M. 54.)

Rappage. Oversize of a casting due to excessive *rapping.*

Rapping. (*a*) The term used in drop forging practice when the die faces meet together. (*b*) Knocking or jarring the *pattern* to loosen it from the sand in the *mould* before withdrawing the pattern.

Rapping Bar. (See RAPPING IRON.)

Rapping Iron. (*Rapping Bar.*) An iron bar used to strike the *draw nail* in order to jar the pattern preparatory to withdrawing it from the mould. (P. 1.)

Rapping Plate. A metal plate attached to a *pattern* to prevent injury to the pattern and assist in loosening it from the sand. (A. 26.)

Rare Earth Metals. These consist of the elements with atomic numbers from 58 to 71 and atomic weights between 140 and 175, e.g. cerium, praseodynium, neodymium, illinium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutecium. Scandium, lanthanum and yttrium are also included in the rare earth groups by many authorities on account of their similarity to the above elements. (V. 11.)

Rare Earths. The oxides of the *rare earth metals.*

Rare Gases. Inactive gases, including *helium, neon, argon, krypton, xenon* and *radon.*

Raschette Furnace. A blast-furnace of elliptical or rectangular section, introduced about 1860, which found considerable use in Germany and in certain districts of Russia for many years. Wooden blowing machines of low-blast output were used and it is assumed that the elliptical furnace was adopted be-

cause under these conditions it gave better yields. (S. 101.)

Rasorite. A trade name for a concentrated form of native sodium borate. It is claimed that Rasorite may be used to replace aluminium wholly or partially in steelmaking.

Rasp. A file in which the teeth have been raised on a blank by means of a punch. It is used where a considerable amount of material is to be removed and a smooth surface is not required.

Rasp Cut. (See CUT.)

Rat. A lump on the surface of a casting caused by a portion of the mould face sticking to the pattern. (A. 26.)

Rat Tailing. (*Worm Marking.*) The occurrence of long, narrow and irregular furrows on the surface of thin flat castings. It is assumed that the defect arises from the moulding sand being out of condition due to over-milling or low permeability. (G. 34.)

Rate of Deposition. (See DEPOSITION RATE.)

Rate of Flame Propagation. The speed at which a flame travels through a mixture of gases. (A. 37.)

Rate of Loading. (*a*) In the United Kingdom the term is synonymous with *rate of stressing*, i.e. it is the variation in tensile stress carried by the specimen per unit of time; it is expressed in tons per sq. in. per minute. (*b*) In the United States the term denotes the variation in tensile load carried by the specimen per unit of time and is expressed in pounds per second.

Rate of Oil Flow. In *powder metallurgy*, the rate at which a specified oil will pass through a sintered porous compact under specified test conditions. (G. 30.)

Rate of Stressing. (See RATE OF LOADING.)

Rate of True Stressing. The variation in true tensile stress per unit of time. It is expressed in pounds per square inch per second. At the nominal plastic yield stress, the instantaneous nominal rate of stressing becomes zero, but the instantaneous true rate of stressing may continue to have a positive value if the cross-sectional area is decreasing. (A. 28.)

Rating. (For *X-ray* tubes.) The product of the allowable current by the peak operating voltage. (A. 27.)

Ratio. For the use of the term in connection with crystals, see AXIAL RATIO.

Rattler. A term sometimes applied in the U.S.A. to a *tumbling barrel*.

Rattler Stars. (See TUMBLING BARRELS.)

Rattling. *Tumbling*.

Rauvite. ($CaO.2UO_3.6V_2O_5.20H_2O$.) A vanadium ore.

Raw Edges. (See CRACKED EDGES.)

Raw Ore. Ore as mined.

Rawson Dial Extensometer. An instrument in which the scale divisions read to 0·0005 in. and the position of the pointer can be estimated to one-fifth of a division. The gauge length is 5 in. and the clamps will take specimens up to 1·5 in. in section. (E. 39.)

Rayflex Fatigue Testing Machine. (See DE FOREST RAYFLEX FATIGUE MACHINE.)

Rayleigh, Lord (John William Strutt). (1842–1919.) A renowned British physicist and the discoverer of *argon*.

Rb. Chemical symbol for *rubidium*.

R.D. Rigid Butt-Joint Test. A test developed by the Armament Research Department for the determination of the relative weldability of various high tensile steels. The test consists of making a multi-pass butt-weld between two restrained plates of the steel in question, its weldability being evaluated by measuring the greatest width of test plate which can be welded without cracking under the conditions of the test, the severity of the test being controlled by the width of the test plate. (M. 142a.)

Re. Chemical symbol for *rhenium*.

Reactant. A substance which undergoes chemical change when in contact with another substance.

Reaction, Chemical. An interaction of substances in which the identity of the materials involved is changed.

Reaction Limit. A term used in *corrosion* for the minimum concentration of an alloy below which appreciable attack of the alloy takes place in a given environment, but above which the alloy is corrosion-resistant.

Reaction Stress. The *residual stress* which could not otherwise exist if the members or parts being welded were isolated as free bodies without connection to other parts of the structure. (A. 37.)

Reactive. Readily susceptible to chemical change.

Reactor. (*a*) A device used in *arc-welding* circuits for the purpose of minimizing irregularities in the flow of welding current. (*b*) A device for controlling fission.

Reagent. A substance, or a solution, used for testing purposes in *chemical analysis*.

Real Fracture Stress. (See TRUE TENSILE STRESS.)

Reamer. A hand- or machine-tool for finishing drilled holes. It consists of a cylindrical or conical shank on which cutting edges are formed by longitudinal or spiral flutes, or in which separate teeth are inserted.

Réaumur Malleable Iron. The European equivalent of *white heart malleable cast iron.*

Réaumur, René Antoine Ferchault. (1683-1757.) A French physicist who is remembered for his work on the conversion of bar iron into steel by the *cementation process*, the Réaumur process for annealing white iron castings, and the temperature scale which bears his name.

Réaumur's Hardness Test. A method of indicating hardness, developed in 1722, using a bar of graduated hardness. The point along this bar at which it was scratched by the material under test was the measure of its hardness.

Réaumur Scale. (°*R*.) A temperature scale on which 0°R is equivalent to the freezing point of water, and 80°R to the boiling point. Therefore, a temperature in degrees Réaumur is equivalent to $\frac{4}{5}$ of the *Centigrade* whilst temperatures in degrees Réaumur are converted to degrees *Fahrenheit* by multiplying by 9, dividing by 4, and adding 32.

Rebonded Sands. Used or reclaimed *moulding sand* restored to usable condition by the addition of new bonding material. (A. 26.)

Rebound Hardness. Hardness as measured by the height of rebound of a body after falling on to the specimen under test from a specified height and under standard conditions.

Recalescence. (See TRANSFORMATION RANGE.)

Recarburization. The addition of carbon to the steel bath, which has been partially decarburized in the steelmaking process, in order to obtain the desired carbon content in the finished steel.

Recarburizer. Any carbonaceous material, a high-carbon pig iron, or a high-carbon alloy, added to molten grey iron or steel to increase the carbon content of the metal. (A. 26.)

Receding Metal. (See BOX HAT INGOTS.)

Receiving Guides. (See GUIDES.)

Recess. (*Markplace.*) In a twist drill, that portion of the drill body between the flutes and the shank provided to facilitate the grinding of the body. Small diameter parallel shank type twist drills are not usually provided with a recess.

Reciprocal Lattice. In crystallography the term relates to a group of points arranged about a centre in such a way that the line joining each point to the centre is perpendicular to a family of planes in the crystal, and the length of this line is inversely proportional to their interplanar distance. (A. 27.)

Reciprocal Proportions, Law of. The weights of two or more substances which separately react chemically with identical weights of a third are also the weights which react with each other, or simple multiples thereof.

Recording Photometer. (See ELECTRODENSOGRAPH.)

Recovery. (*a*) The removal of the stressed condition of the lattice during annealing following *cold working*. It takes place at temperatures lower than those required for *grain boundary* migration or *recrystallization*. (*b*) The amount of an alloy addition retained in a cast of metal or of a substance separated in a chemical process.

Recrystallization. (*a*) In a metal, the replacement of crystals which have been deformed in *cold working* by new, equiaxed and unstrained crystals. The process is achieved by heating and holding the metal at a suitable temperature. The greater the amount of cold work carried out on the metal, the lower will be the temperature of recrystallization. (*b*) In a salt, the production of new crystals by dissolving them, and concentrating the solution, thus allowing the crystals to re-form.

Recrystallization Annealing. Heating above the recrystallization range to eliminate the cold worked structure. (See RECRYSTALLIZATION.)

Recrystallization Temperature. The lowest temperature at which the distorted grain structure of a cold worked metal is replaced by a new, strain-free grain structure during prolonged annealing. Time, purity of the metal, and prior deformation are important factors. (A. 27.)

Recrystallization Welding. (See FORGE WELDING.)

Rectification. (*a*) The conversion of alternating current to unidirectional current. (*b*) In *argon arc welding*, the term means the complete loss of a reverse polarity current loop, i.e. the argon arc acts as a half-wave rectifier.

Rectifier. A device for converting alternating current to unidirectional current.

Rectifier Anode. The electrode of the *rectifier* from which the current flows into the arc.

Rectifier Cathode. The electrode of the rectifier into which the current flows from the arc.

Recuperative Furnace. A *reverberatory furnace* in which the air for combustion (under a slight pressure) is preheated by entering through pipes in the chimney flue, around which the products of combustion pass, the gases always passing through in the same direction without reversal.

Recuperator. Equipment for recovering heat from hot spent gases and using it

for the preheating of incoming fuel or air. It is a continuous operation, in which the incoming gases pass through pipes surrounded by a chamber through which the outgoing gases pass. (Cf. REGENERATORS.) (A. 26.)

Recurrent Lap. (See TEEMING LAP.)

Red Cobalt. A cobalt ore consisting of cobalt arsenate.

Red Hardness. The hardness of a metal, commonly high-speed tool steel, which is retained even at red heat. (See TEMPER HARDNESS.)

Red Heat. The temperature at which a metal appears red hot when viewed in a dark room, i.e. about 550° C.

Red Lead. Red oxide of lead, Pb_3O_4.

Red Manganese. (See RHODOCROSITE.)

Red Shortness. Brittleness or low shear resistance in steel when red hot, causing it to fly when under the hammer or to split during rolling. It is usually due to a high sulphur content, together with low manganese, which thus causes the sulphur to be present in the form of iron sulphide. (N. 18.)

Red Stain. Stain formed on brass by volatilization of zinc during annealing or by redeposition of copper during pickling. (A. 27.)

Reducing Agent. A substance capable of supplying electrons to another substance and thus bringing about *reduction*.

Reducing Atmosphere. An atmosphere containing elements or compounds which react with or neutralize the effect of oxygen. Such atmospheres prevent oxidation or bring about chemical change involving a decrease in the state of oxidation.

Reducing Flame. (*Carburizing Flame.*) A flame containing a carbonaceous gas in excess of that required to produce a neutral flame and thus effecting *reduction*.

Reduction. (*a*) The reverse of *oxidation*. A chemical change involving a decrease in the state of oxidation. For example, the term is applied to the chemical reaction by which iron is produced by removal of oxygen from the ore, in the *blast furnace*. (*b*) The amount by which the thickness of a material is reduced in a single *pass* through the *rolling mill* (*pass reduction*), or the total amount by which the thickness of the material is reduced at the completion of the rolling operation (*total reduction*). It may be expressed either as a fraction of thickness before rolling or as a linear measurement.

Reduction Cell. A pot or tank in which a water solution of a metallic salt or a fused salt electrolyte is electrolytically reduced to form free metals. (A. 27.)

Reduction of Area. (*a*) The percentage decrease in the cross-sectional area of a *tensile test piece* caused by the *waisting* or *necking* of the specimen. It is expressed as a percentage of the original area of the test piece and is a measure of *ductility*. (*b*) The percentage decrease in cross-sectional area of bar or wire after *rolling* or *drawing*.

Reduction of Area Gauge. A device which measures and records the reduction in cross-sectional area of the specimen during a tension test. A feature of one form of the apparatus is a fine wire or thread having one fixed end and one weighted end maintaining tension along the wire. An intermediate portion of the wire is wrapped around the specimen at a point where the most marked reduction of area can be expected. Adjacent to the testing machine is placed a recorder with a rotating drum for providing continuous records. A recording pen is mounted on a rack with teeth meshing those of a pinion on a shaft. This pinion has an integral pulley, around which the wire is wound one turn. It is evident that as the diameter of the specimen contracts with elongation, the length of wire around its circumference will decrease, thus imparting motion to the pinion and recording pen. In another form the device consists of a flat piece of steel containing a tapered slot. This is pulled over the necked section of the test piece and the reduction of area read off on a scale along the edge of the tapered slot. (E. 71.)

Redux Process. (See PEEL TEST.)

Reed. An internal discontinuity originating from a subcutaneous *blow hole* which has become oxidized and has been elongated during rolling.

Reed Vibrometer. A small electromechanical instrument for the study of vibration, using the phenomena of resonance induced in a thin steel reed. The instrument probe is placed in contact with the vibrating structure, e.g. machine frame, floor, bridge, etc., and the effective length of the reed is varied, by means of the knob on the side of the vibrometer, until resonance is observed visually. The frequency is then read direct on the calibrated scale.

Reek. To smoke the inside of *ingot moulds*, e.g. by means of burning tar, prior to *teeming*.

Reeler. (*a*) A machine used for straightening bars. (*b*) A machine used in the production of seamless steel tubes. The reeler burnishes the inner and outside surfaces of the plug rolled tubes by means of cross rolls and a cylindrical mandrel held on the inside of the tube between the rolls.

Reeling. (*Spinning.*) Straightening round bar, wire or tube by feeding it between contoured steel rolls in a direction approximately parallel to the principal axes of the rolls. The operation may be carried out either in the hot or cold condition.

Reeve Weld-Cracking Test. A tied fillet-weld test in which two superimposed plates measuring 10 in. by 7 in. and 6 in. square, respectively, are clamped to a heavy rigid baseplate by means of four 1 in. diam. bolts. The rigidity of the set-up is increased by three "anchor" fillet welds deposited along three sides of the 6 in. square plate. When these are cold, the fourth fillet, which constitutes the test weld, is deposited under chosen welding conditions. When the test run has reached room temperature, three cross-sections are cut from it, and examined for cracks, microstructure and hardness. In the *Miniature Reeve Test* the plates are bolted together with a single bolt. The top plate is 3 in. by 1¾ in. and the bottom plate 4 in. by 3¼ in., both plates being of the same thickness, ¼, ½, and 1 in., depending upon the thickness of plate tested. (L. 17.)

Referee Method. A method of test used by the mutual agreement of contracting parties for establishing an acceptable value in settlement of disputed test results.

Refined Bar Iron. (Refined wrought iron bars.) Iron bars rolled from a *muck bar* pile, or from a box pile of muck bars and wrought iron scrap bars free from steel, all bars running the full length of the *pile*. (A. 28.)

Refined Pig Iron. Re-melted *pig iron* of guaranteed analysis.

Refining. (*a*) The term as applied to metals in general, refers to operations performed after the crude metals have been extracted from their ores, in order to obtain them in a condition of higher purity. (*b*) The removal of impurities and metallic oxides from the molten bath by the reaction of the slag and certain additions. (*c*) (*Grain Refining*).

Refining Bar Test. A test which consists of subjecting two standard bars, in different heat-treated conditions, to a heat gradient in a specially designed furnace, prior to Brinell testing. The test results are given in the form of graphs, thus indicating the relation between Brinell hardness and the temperature (i) from which the steel has been quenched subsequent to annealing, and (ii) at which the steel has been tempered after hardening; in addition, it is possible to relate the Izod impact value to the treatment temperature and to study the nature of the fracture. (M. 173.)

Refining Temperature. A temperature employed in heat treatment to refine the structure, in particular, the *grain size*. Usually just above Ac_3 in steel.

Reflecting Galvanometer. (See Mirror Galvanometer.)

Reflecting Microscope. An instrument in which the objective lens system is replaced by a pair of concave and convex mirrors. (I. 63.)

Reflecting Pyrometer. An instrument for the measurement of true temperature which consists essentially of a polished hemisphere, with an aperture at its zenith, clamped against a glass filter. Above the aperture is a second filter and a vacuum photocell. In use the pyrometer is placed with the three studs on the rim lightly in contact with the heated surface. (S. 69.)

Reflectogage. An instrument used primarily for the measurement of the thickness of materials, by means of ultrasonic waves. (S. 77.)

Reflector Sheet. An *Alclad* product containing on one side a surface layer of high-purity aluminium superimposed on a core or base alloy of commercial-purity aluminium, or an aluminium-manganese alloy. The high-purity coating imparts good polishing characteristics and the core gives adequate strength and formability. (A. 27.)

Reflectoscope. An instrument for the *ultrasonic testing* of metals which uses a quartz crystal to transform impressed electrical pulses into mechanical vibrations, which are propagated in the metal and are partly reflected back towards the crystal when they encounter flaws or discontinuities. The crystal changes these echoes back into electrical pulses, and the time interval between the instant of pulse transmission and the instant of echo return is a measure of the distance of the discontinuity from the crystal. (F. 44.)

Reflex Printing. A method of recording surface structures in which the etched surface is placed downwards on the sensitized side of a sheet of photographic printing paper supported by a sheet of clear glass, under which is a 60 watt lamp in a white reflector covered by a reflex screen. The time of exposure is about four seconds and development is carried out in a suitable solution followed by washing and normal fixing. The result is a paper negative from which positives are made by contact printing. (T. 18.)

Reflex Vickers Hardness Testing Machine. The machine employs a pyramidal indenter in which the image

of the point at which the indenter contacts the surface of the specimen under test can be reflected on to a ground glass screen, by means of which the lengths of the diagonals of the impression can be read directly. (W. 53.)

Reflux Condenser. A form of chemical apparatus, consisting of a cooling coil mounted on a vessel containing a boiling solution, which continuously condenses the escaping vapour and returns it to the vessel.

Refluxed. A term applied in testing corrosion resistance to boiling solutions in which the escaping vapour is condensed and returned to the solution containing the metal under test.

Refraction. (See INDEX OF REFRACTION.)

Refractive Index. (See INDEX OF REFRACTION.)

Refractivity. This is given by (n–1) when n is the *index of refraction*, the specific refractivity is given by $\frac{n-1}{d}$ where d is the density. Molecular refractivity is the product of specific refractivity by the molecular weight.

Refractoriness. The index to the heat-resisting properties of a *refractory*.

Refractoriness-Under-Load. The resistance of a *refractory* to the combined effects of heating and loading.

Refractory. (*a*) The quality of resisting heat. (*b*) A *ceramic* material which will not fuse at high temperatures, e.g. fireclay, silica, dolomite and magnesite, used for such purposes as furnace linings.

Regenerative Chambers. (See REGENERATORS.)

Regenerative Furnace. A type of *reverberatory furnace*. e.g. a *Siemens open-hearth furnace*, in which the air and gaseous fuel are preheated by passing through *regenerators*.

Regenerative Quenching. The double quenching treatment given to case-hardened steel. Carbon case-hardening steels are first quenched from a temperature of 870° to 900° C. and then from 760° to 780° C. and tempered up to about 200° C. The first quench is intended to refine the core and the second is to refine and harden the case.

Regenerators. (*Regenerative Chambers.*) These consist of two pairs of chambers, one for gas and one for air in each pair, each filled with a checkerwork of refractory bricks. The object of the checkerwork is that the bricks may absorb the heat from the hot waste gases as they pass through on their way from the furnace to the chimney. When the checkerwork of one pair of chambers is heated, the flow of the heated gases is reversed, to pass through the other pair of cool chambers, whilst the hot checkerwork gives up its heat to the incoming air and *producer gas* on their way to the furnace. (See OPEN HEARTH FURNACE.) (Fig. 8.)

Register. (See CORE PRINTS.)

Regulator. A device for controlling the delivery of gas at some substantially constant pressure regardless of variation in the higher pressure at the source. (A. 37.)

Regulus. (*a*) The metallic part of an ore that separates from the slag during melting, by sinking to the bottom in a furnace or crucible. (*b*) Refined antimony. (*c*) (See REGULUS METAL).

Regulus Metal. A lead-antimony alloy. British Standard 355 covers four grades containing from 6% to over 12% antimony respectively. Regulus metal has considerable resistance to acid corrosion and is used for the construction of acid tanks, pumps, etc.

Rehbinder Effect. The theory advanced by Rehbinder, and others, that surface-active liquids reduce the mechanical strength of single and polycrystalline metals. It is suggested that the effect is due to the destruction of the strengthening oxide film. (A. 44.)

Reheater. A furnace designed for the re-heating of steel after it has had some work performed on it.

Reheating. Raising iron or steel to a uniform and suitable temperature for hot working.

Reheating Furnace. A furnace for reheating ingots prior to hot working.

Reichert Meissel Number. The number of ml. of N/10 caustic potash required to neutralize the volatile acids liberated from 5 gram of fat.

Reinforced Concrete. (See CONCRETE.)

Reinforcement. As applied to welding, the term refers to (*a*) the surplus metal on the face of a fillet weld above that required to form a right-angle triangle section. (*b*) The surplus metal on a butt weld lying above the surface of the plate.

Reisert Process. A process, for the production of composite castings of steel and bronze. It involves a zinc coating of a forged steel backing in a molten zinc bath, and the subsequent casting-on of the bronze bearing layer. The intermediate zinc layer bonds on the one side with the steel backing and on the other side with the cast bronze. (See MASCHER PROCESS.) (S. 31.)

Reladling. A process designed to obtain uniform bath composition. A portion of the metal is tapped out, then poured back into the furnace over the lip of the ladle, thus duplicating, to some

extent, the type of mechanical mixing that occurs during the tapping of a heat. (G. 45.)

Relative Density. (*Density Ratio.*) (*a*) The ratio of the density of a gas to that of hydrogen under similar conditions of pressure and temperature. (*b*) *Specific Gravity.*

Relative Humidity. The ratio, expressed as a percentage, of the amount of water present in a given volume of air at a given temperature to the amount required to saturate the air at that temperature.

Relative Valency Effect. The tendency of a metal of higher *valency* to dissolve one of low valency rather than vice versa.

Relative Volume. The determined volume of a *green* or *sintered compact* divided by the volume of the massive metal of the same composition for the identical weight. (G. 30.)

Relaxation. The effect produced when a material is stretched to, and held at a given elongation, as in bolts, particularly at elevated temperatures. Creep tends to elongate the bar and release the load. Elastic shortening balances this effect and total strain remains constant. Plastic elongation can be measured by the decrease in stress. (W. 26.)

Relaxation Coercive Force. (See COERCIVE FORCE.)

Relief Sprue. A vertical channel in a mould. It is of approximately the same size as the *downsprue*, and is connected to the runner for the purpose of relieving pressure surge during pouring. (See also SPRUE.)

Reluctance. (R.) The reciprocal of permeance, i.e. a measure of the resistance to magnetization.

Reluctivity. (v.) The reciprocal of the permeability of a medium. (A. 28.)

Reluctometer. An instrument for checking the uniformity in the quality of mass-produced tools and other steel parts by measuring the magnetic reluctance of the steel. (B. 37.)

Rem Cru Skull Melting. A method of melting titanium which, it is claimed, prevents melting contamination. Arc melting is employed and a thin skin from the melt is frozen on a water-cooled copper crucible. Thus, the titanium is melted in itself. However, the amount of metal molten at any time is quite limited because of the rapid heat transfer through the water-cooled copper mould. Ingots are formed in such equipment by gradually feeding in the charge and melting it. Only the very top of the ingot is molten. (B. 119.)

Remanence. (*Remanent Induction.*) (B_d.) The *magnetic induction* which remains in a magnetic circuit after the removal of an applied electro *magnetomotive force*. If there is an air gap in the magnetic circuit, the remanence will be less than the residual induction. (A. 28.)

Remanent Induction. (See REMANENCE.)

Renault Hot Hardness Tester. This machine is designed for the measurement of the hardness of metals at temperatures up to 900° C. with the object of reducing the necessity for creep testing. The machine employs a pyramidal indenter with a square base, similar to the Vickers, under a load of 1, 3, 7 or 9 kg. at any selected temperature between ambient and 950° C., whilst the load may be applied for any specified time of more than 8 seconds. Up to 23 impressions may be made on one test piece which is in the form of a disc, 37 mm. in diam., and 5 mm. thick. After cooling, the specimen is removed from the machine and the impressions measured under an ordinary measuring microscope. The equipment includes a furnace with a regulator and temperature recorder and vacuum pump for maintaining a vacuum in the furnace, thus avoiding oxidation of the test piece.

Renn-Wälz Process. A method of reclaiming iron and other metals from the waste materials produced in the smelting of zinc and lead ores. This material, which cannot be treated in the blast furnace because of the presence of other metals, is brought up to 1000°C. in the preheating zone of the kiln by the countercurrent gases, and this drives off CO_2 from the carbonates. The process differs from the *Krupp-Renn* method in that it is a volatilization process for recovering molten metals in oxide form. The metal vapours are oxidized by excess air and carried off in the flue gases from which they are subsequently filtered. (T. 10.)

Rennerfelt Furnace. An independent arc furnace, i.e. one in which the arc is maintained between the ends of the electrodes and, therefore, does not depend on the material forming the charge. It has three electrodes, the third electrode being introduced in a vertical plane at right angles to the existing electrodes. The object of the extra electrode is to attain effective heat transference by deflecting the arc on to the metal. The furnace consists of a cylindrical steel shell lined with firebrick and then (usually) with dolomite, surmounted by a removable dome-shaped roof, generally lined with silica bricks. It is tilted for pouring.

The graphite electrodes are up to 6 in. in diameter, and as they are consumed, fresh lengths are joined on. Where the electrodes enter the furnace, they pass through copper or bronze water-cooled cylinders. The vertical electrode can be lowered and the side electrodes tilted in a vertical plane, so that, as the solid charge melts and sinks in the furnace, the arc can follow it. The extremities of the side electrodes are normally kept about 20 in. apart. In the steel industry, this class of furnace has now been superseded by the direct-heating type.

Repeated Scrape Abrasion Tester. A device in which wire insulation is abraded under constant load, the number of strokes to failure being taken as a measure of abrasion resistance. In the *increasing load tester*, the wire is abraded under a constantly increasing load, the load at failure being taken as a measure of the abrasion resistance. (M. 16.)

Repeated Stress Test. (See FATIGUE.)

Repeaters. *Looping channels* employed in certain types of *rolling mills*. They are semi-circular in shape and are used to guide the piece from one pass to the next.

Repeating Compound. A carburizing agent which may be used several times.

Rephosphorization. A condition which may be brought about in the *basic process* by the reduction of some of the phosphoric acid in the slag, when it then re-enters the molten steel.

Replaceable Hydrogen. The hydrogen *atoms* in a molecule of an acid which are replaceable by metal atoms when the acid is neutralized with a base.

Re-pressing. In powder metallurgy, the pressing of a previously pressed and sintered compact for the purpose of altering physical properties or size. (A. 27.)

Re-rolling Quality. Hot rolled blooms, billets or slabs from which the surface defects have not been completely removed, and which are intended for further rolling into bars, plates, sheet or strip.

Residual Elongation. The extension measured one minute after rupture of a tensile specimen, by fitting together of the broken ends, expressed as a percentage of the original length of the measured elongating section. The length of the measured elongating section must be stated. (A. 28.)

Residual Induction. (See INDUCTION, RESIDUAL.)

Residual Stress. (*Locked-Up Stress.*) The stress which exists in an elastic solid body in the absence of, or in addition to, the stresses caused by an external load. Such residual stress may be brought about by (1) deformation, caused by cold-working, as in drawing or stamping; (2) change in the specific volume due to thermal expansion or contraction or to *electro-* or *magneto-striction*, or (3) by the joining together of structural parts by force, e.g. *welding*.

Residuals. The elements ordinarily present in steel in small quantities without definite intent on the part of the steelmaker.

Résilacié Test. (See SCHNADT NOTCH IMPACT TEST.)

Resilience. A general term for the capacity of an elastically strained body to spring back on removal of the load. This property is conferred by the potential energy stored up in an elastically strained body and given out when the load is removed. It is usually expressed as foot pounds per cubic inch. The *proof resilience* is the greatest amount of energy that can be stored up by a body strained only elastically.

Resin. A solid or semi-solid amorphous organic compound or mixture of such compounds, with no definite melting point and no tendency to crystallize. Resins may be of vegetable or animal origin (e.g. *shellac*), or may be synthetic. Natural resins are distinguished from gums in that the resins are insoluble in water, but certain synthetic water-soluble materials are referred to as resins.

Resintering. The sintering of a re-pressed compact under conditions identical or different from those prevailing at the first sintering operation. (G. 30.)

Resistance Brazing. A process in which the heat is obtained by passing an electric current through contact resistance between the areas to be brazed. In one process of this type the heat is generated in the electrodes and transferred to joint members by conduction. This is sometimes called *incandescent carbon brazing* because the heat is usually generated in carbon electrodes. In another type the heat is generated in the members. (C. 15.)

Resistance Butt Welding. A resistance welding process in which the components are butted together and maintained so under pressure until the weld is completed, the weld being effected simultaneously over the entire contact area of the parts being joined. (See UPSET WELDING and FLASH WELDING.)

Resistance Flash-Butt Welding. (See FLASH WELDING.)

Resistance Forge Welding. The method consists of applying pressure to the

work, followed by interrupted current and finally superimposing a hammering action on the electrode. Under high pressure and with sufficient heat, the surfaces to be welded are brought into such intimate contact that when additional impact-pressure and intermittent heat are applied, a forged weld of superior strength is obtained.

Resistance Heating. Heating by passing an electric current through a body which presents considerable resistance to its flow.

Resistance Percussive Welding. (See PERCUSSION WELDING.)

Resistance Projection Welding. (See PROJECTION WELDING.)

Resistance Seam Welding. (See SEAM WELDING.)

Resistance Soldering. In resistance soldering, the joint forms a part of the electric circuit. Heat is brought about by the resistance at the joint when a large current is passed. The parts to be soldered are held between two electrodes in the form of tongs or clamps. When the current is applied, the preplaced solder melts by local heating. The pressure is maintained until the solder solidifies. (M. 9.)

Resistance Spot Welding. (See SPOT WELDING.)

Resistance Pyrometer. An instrument that functions on the principle that the electrical resistance of metal changes with temperature. The change in resistance of a coil of fine wire, usually platinum, is calibrated with temperature.

Resistance Welding. A process effected by passing a heavy electrical current through the pieces of metal to be joined. The metals being thus raised to welding temperature, the parts are then forced together by pressure. In this method no external heat is used, the heat required to make the weld being generated by the resistance presented by the metal being welded to the passage of an electric current.

Resistance Welding Electrode. (See ELECTRODE.)

Resistance Wire. Wire presenting high resistance to the flow of electric current and having considerable resistance to oxidation at elevated temperatures. Suitable compositions for the wire include (i) 80% nickel with 20% chromium, (ii) 84% copper, 12% manganese with 4% nickel. Resistance wire is used for the manufacture of electrical heating elements, resistors, etc.

Resolved Shear Stress. The vectorial component of load acting on the shear plane, divided by the shear plane area. (A. 27.)

Resolving Power. The ability of a microscope to distinguish the individual details of a fine structure.

Resonant Frequency Inspection. A non-destructive test which is a refinement of the traditional method of testing a metal part by striking it with a hammer and listening if it rings true. The new development employs a *tachometer*, coil magnet or *oscilloscope* to measure the frequency of a part which can be vibrated. It is merely necessary to clamp one end of such a piece in a vice and direct an air blast at the other, thus causing it to vibrate at its natural frequency. If one of several supposedly identical pieces vibrates at a lower frequency than the others, it is quite likely to be defective. Samples found to be faulty by this means have failed prematurely in the fatigue test, thus corroborating the existence of defects. (M. 113.)

Resonant-Type Fatigue Testing Equipment. A type of fatigue testing machine in which the loads are applied by inertia forces from two heavy masses between which the test specimen is suspended. The system operates as a tuning fork which subjects the specimen to vibratory bending stresses; the natural frequency of the assembly is usually 40 to 100 cycles per second. (D. 40.)

Resquaring. Shearing sheets to accurate dimensions and shapes.

Rest Bar. (See CRAMP BAR.)

Restoring. A term sometimes applied in the U.S.A. to the process of *grain refinement*.

Restrainer. (See PICKLING.)

Restriction Cracks. (See PULL CRACKS.)

Restrike on Draw. *Restriking* a forging on the tempering heat of a heat treatment to produce closer alignment of sections. (U.S.A.)

Restriking. (*Tapping*.) A single blow given to a *drop forging* in the dies to correct any distortion which remains after clipping.

Restriking Voltage. (*R.V.*) In welding, the voltage which appears across the gap immediately after arc extinction. This voltage may be considered as composed of two components, one of mains frequency and a transient component (which may be oscillatory), referred to as the transient R.V.

Retained Strength. That tenacity (*compressive*, *shear*, *tensile* or *transverse*) attained by a sand mixture after being subjected to a cycle or cycles of heating and cooling which approximate to foundry practice. (A. 26.)

Retentivity. (B_{rs}.) The property of a magnetic material measured by the

maximum value of the *residual induction*. (A. 28.)

Retigraph. An instrument used in *X-ray crystallography*. It consists of a moving-film apparatus which provides an undistorted photograph of a reciprocal lattice plane. By photographing a number of parallel successive lattice planes and placing these at their appropriate distance and orientation, the complete reciprocal lattice may be obtained. (J. 25.)

Retort. (*a*) A metallic or refractory-lined vessel for distilling metals, alloys and ores. (*b*) A spherical glass vessel with an extended side tube, used in a chemical laboratory for the distillation of liquids.

Reverberatory Furnace. A furnace in which the ore or metal is exposed to the action of flame, but is not in contact with the fuel. The principle of the furnace is the deflection or reverberation of the heated gases from the sloping roof on to the metal.

Reverse Bend. (See BEND TEST.)

Reverse Chill. (INVERSE CHILL.)

Reverse 18-8. A steel containing 8% chromium and 18% nickel which is the reverse of the normal austenitic corrosion-resistant steel containing 18% chromium and 8% nickel.

Reverse Polarity. The arrangement of direct current arc-welding leads wherein the work is the negative pole and the electrode is the positive pole of the welding arc. (A. 37.)

Reverse Torsion Test. A test applied to wire; the sample is twisted axially for a specified number of times in one direction, and then for the specified times in the opposite direction. The test requires that the specimen should remain free from cracks.

Reversible Process. A process in which, electrochemical transformations having occurred, reversion to the original state is possible within the system. (B. 103.)

Reversible Reaction. A chemical change in which the products of reaction may be made to return to the original substances by slightly changing the conditions of, for example, temperature, pressure and concentration; an equilibrium condition in which the extent of reaction in either direction is determined by pressure and temperature.

Reversing Mills. (See ROLLING MILLS.)

Reversion. A break or temporary reversal in the curve of variation of a property with increase in temperature. (J. 4.)

Revolving Crystal. A method for crystal analysis, using a small single crystal that rotates uniformly through many complete rotations during the time of exposure. (A. 27.)

Reynolds, William. (1758–1803.) An Englishman who patented, in 1799, the use of manganese oxide for the conversion of natured or malleable iron in the finery, bloomery, puddling or other furnace.

Reynolds' Crack Detector. An electromagnetic equipment for the inspection of welded tubular structures. This equipment is for applying current to tubular structures for magnetic powder tests to detect cracks. Special clamps are provided for conveying the current to the tubes for longitudinal tests, and a single-loop induction ring is supplied for making transverse tests. (M. 29.)

Reynolds' and Smith's Fatigue Testing Machine. An alternating stress testing machine, the mechanism of which is essentially that of an ordinary reciprocating steam engine. A weight is suspended from the lower end of the test piece, while the upper end is attached to a connecting rod receiving periodic motion by means of a crank rotating with uniform angular velocity. Tensile and compressive stresses are induced in the specimen at the bottom and top ends, respectively, of the stroke. (G. 36.)

Rh. Chemical symbol for *rhodium*.

Rhenium. (*Re.*) *Atomic weight* 186·31. *Specific gravity* 21·02. Melting point 3180° C. ± 20° C. A silver-white metal which chemically resembles manganese. The most striking feature displayed by rhenium is its extreme susceptibility to work hardening. In the fully annealed condition, the Vickers hardness number of pure rhenium is about 150 to 200, but after only 10% to 15% reduction in cross-sectional area by cold working, the Vickers hardness number becomes about 550. The hardness given to rhenium by cold working is, moreover, retained on heating, in non-oxidizing surroundings, to an extremely high temperature. Very little, if any, softening can be detected after heating to temperatures as high as about 1300° C. and it is necessary to heat to 1500° to 1700° C. to produce any appreciable softening. Even higher temperatures are probably necessary in order to produce complete recrystallization. Other outstanding properties are its high melting point, and the ease with which it can be alloyed with tungsten, nickel, cobalt, tantalum, platinum, rhodium, iridium, gold and iron. Rhenium alloys are reported to be highly resistant to corrosion. *Iridium* and *rhodium* alloys are more easily worked if alloyed with 10% rhenium,

and such alloys can be drawn into fine wires or rolled into thin ribbons. Up to the post-war period, rhenium was regarded as an extremely rare metal, its only known source being in Mansfeld, Germany, but during the early 1950's other sources were found, notably in Siberia, and in the States of Nevada, Utah, Mexico and Arizona in the United States. In its native state, rhenium occurs as a sulphide, closely associated with molybdenite, and usually in the presence of copper. Its thermoelectric properties render it an excellent material for thermocouples and it has given outstanding performance in electrical contacts. A number of electronic applications are under investigation.

Rheology. The science of the deformation and flow of matter. (S. 33.)

Rheostat. A resistor with means for readily varying the amount of resistance in circuit.

Rheotropic Embrittlement. A term used to describe a type of brittleness occurring under severe service conditions, e.g. at low temperatures, which can be overcome, or at least partially removed, by cold work at relatively high temperatures. (R. 29.)

Rho Ratio. (See POISSON'S RATIO.)

Rhodanizing. The process of electroplating with *rhodium*. It is most commonly used for rendering silver untarnishable.

Rhodium. (*Rh.*) *Atomic weight* 102·91. *Specific gravity* 12·5. *Melting point* 1965° C. A silver-white metal of the platinum group. It is obtained as a by-product in the extraction of platinum from the residues from nickel and copper refineries. In the pure state it is ductile and malleable and is resistant to most acids. Platinum-rhodium alloys containing either 10% or 13% rhodium are used in pyrometry for high temperature *thermocouples*. Electro-deposited rhodium possesses considerable hardness and is extremely resistant to wear. (See also RHODANIZING.)

Rhodocrosite. (*Red Manganese, Manganese Spar, Manganese Ore, Spathic Manganese Ore.*) A manganese ore consisting essentially of manganese carbonate.

Rhodonite. Manganese silicate, MnO. SiO_2, a constituent of acid steelmaking slags.

Rhombohedral. (Concerning crystals.) Having parallel 6-fold rotary-reflection axes, or a single set of parallel 3-fold rotation axes, in either instance without planes of symmetry perpendicular thereto, and with or without other elements of symmetry. The typical rhombohedral crystal has three equal axes mutually inclined at an angle not usually equal to 90 degrees. (A. 27.)

Rhombus. A quadrilateral figure having all its sides parallel and equal in length but whose angles are not right angles.

Ribmet. A form of expanded steel used for the reinforcement of concrete.

Richards, Theodore William. (1868–1928.) An American chemist who determined the atomic weights of various elements.

Richter, James Benjamin. (1762–1807.) A German chemist who is remembered chiefly for his work on chemical equivalents.

Richter Test. A special hardness test using very low pressures down to 0·01 g. It consisted of a balance, in the end of which a cutting point was fixed. Having first used a 90° diamond point, Richter found it wore heavily and he increased the conical angle to 120°. (Z. 8.)

Rider. (*Jockey.*) A small weight of gold or platinum wire placed on the beam of an analytical balance to obtain final adjustment for the most accurate readings.

Rider Sheets. Sheets placed on the rollers of *roller hearth* type heat treatment furnaces to support the material being treated and prevent it from coming in contact with the rollers.

Rider Strips. Strips of metal placed over the surfaces of steel parts prior to annealing, as a protection from mechanical damage.

Ridge Projection Weld. A weld where ridges that have been formed in the overlapping parts lie at an angle to each other and the parts are joined by the resistance welding of the points of intersection of the ridges. (B. 105.)

Riehle Impact Testing Machine. A tension impact testing machine having two anvils of equal length. The specimen is threaded at both ends, one end being screwed into the rear of the tup and the other into the impact crosshead. As the tup swings through the lowest point in its arc, the crosshead strikes the anvils, causing the entire inertia of the tup to be exerted axially on the test piece. The value is expressed in ft. lb.

Riemer Process. Retaining the heat on the top of an ingot by means of a producer gas jet with the object of eliminating *piping*. (D. 1.)

Riffler. A type of file, usually double ended with a smooth centre, providing hand hold. Generally used in stone and wood carving.

Riffles. (See COCKLES.)

Righi Leduc Effect. (See LEDUC EFFECT.)

Right-Hand Welding. (See BACKHAND WELDING.)

Rigidity-Modulus. (See MODULUS OF RIGIDITY.)

Rim Segregate. (See SKIN SEGREGATE.)

Rimming-Steel Ingots. The structure of this type of ingot is characterized by an outer envelope or rim of solid and comparatively pure steel, with the interior or core of a less solid and less pure character. Such ingots are made from steel of an effervescing nature, that is, steel in which the deoxidation, either in the ladle or in the mould, has been intentionally limited, with the result that a free ebullition of gas progressively takes place during the freezing of the ingot. The steel freezes progressively from the mould wall, whilst the interior remains liquid and in a state of violent ebullition. The centre may solidify naturally, but is usually chilled by a *cooler plate*. The abundance of sparks emitted during freezing is peculiar to this class of steel. Such steel usually contains less than 0·15% of carbon and less than 0·50% of manganese, with only traces of silicon. Usually, in a very low-carbon steel, where the ratio of FeO to carbon is high, the envelope or rim is substantial and free from *blowholes*, whereas at the other end of the scale, where the ratio of FeO to carbon is low, as it may be in the case of a 0·25% carbon steel, the envelope or rim is less substantial, less defined, and contains blowholes near the skin, usually over the whole length of the ingot. Other factors being constant it would appear that, as the ratio of FeO to carbon falls, the thickness of the envelope decreases and blowholes first make their appearance in the bottom portion of the envelope, subsequently extending therein to the full length of the ingot. In all cases, gas holes of a globular form lead off from the inner surface of the envelope, and within this region the centre portion of the ingot is less pure than the average composition, and contains globular blowholes to a greater or less extent. (I. 78.)

Ring Type Cold Strip Mill. The mill is of the three-high type with a small middle roll. Instead of transmitting the rolling pressure from the rotating rolls through bearings, chocks, and adjusting screw to the mill housing, the rolling pressure is directly transmitted to and absorbed by two large rings in contact with the necks of the large rolls. These rings are suspended on the necks of the top and bottom rolls and are free to rotate with the rolls. The rolls are kept in position by light roller bearings, mounted on the extension of the roll necks, with the chocks located in the windows of a light cast-iron frame. The bearings of the bottom roll are fixed in the frame, those of the middle roll are mounted in a yoke-shaped member, suspended from an adjustable spring device at the top of the frame, while the top roll bearings are only held in the horizontal direction. By tightening the springs, the middle roll, the top roll and the rings are lifted upwards, until the inner peripheries of the rings make contact with the bottom roll necks. The bottom roll, being connected to the drive, sets the rings, as well as the top and middle rolls, in rotation by virtue of the frictional force produced by the initial spring pressure. (S. 107.)

Ringing. A term given to the circular groove which appears in a wire drawing die as the result of wear, close to the place at which the wire makes contact with the die wall. It is present in every worn die, of whatever material it is made. (W. 66.)

Rinman Scale. A Swedish standard scale for the estimation of slag inclusions in iron and steel. This scale consists of a series of micrographs, designed to show different typical fields of view, and arranged in groups according to the form and distribution of the inclusions and numbered according to their quantity. In the practical application, the appearance of the specimen under the microscope is compared with the micrographs in the scale. (R. 28.)

Rippled Surface. Wave-like markings on the surface of an ingot caused during teeming by successive interruptions in the rise of the molten steel near the walls of the *ingot moulds*. They may also be due to the use of a mould which has been itself teemed in this way, thus showing similar markings on its inside faces which are then reproduced on any ingot cast in this mould.

Riser. (*a*) An opening in the top of a *mould*. It acts as a reservoir of molten metal which prevents the formation of cavities in the casting as it contracts on solidification. Secondly, it allows gases to escape as the molten metal rises in the mould, and thirdly, it indicates to the moulder when the mould is full. On removal of the mould, the riser forms a projection on the casting from which it is finally cut away. An *open riser* is a conventional form of riser usually located at the heaviest section of the casting and extending through the entire height of the *cope*. (*b*) A term sometimes applied to a *rising steel ingot*.

Riser, Blind. (See BLIND RISER.)

Riser Contact. (See RISER PAD.)

Riser-Gating. The practice of running metal for the casting through the riser to help directional solidification. (A. 26.)

Riser Height. The distance from the top of the *riser*, when liquid, to the top of the riser neck. Riser height when solid may be several inches less than when liquid because of loss of feed metal to the casting. (A. 26.)

Riser Neck. The connecting passage between the riser and casting. Only the height and width, or diameter, of the riser neck usually are reported, although the shape may be equally important. (A. 26.)

Riser Pad. (*Riser Contact.*) An enlargement of the riser neck where it joins the casting. The purpose of the pad is to prevent breaking in of the riser when it is struck or cut from the casting. (A. 26.)

Rising Steel Ingots. (*Blown Ingots.*) (*Unkilled Steel.*) Steel in which there is an evolution of gas during solidification, thus causing the metal to rise in the mould. This is due to the fact that the heat is *wild*, i.e. it has not been sufficiently deoxidized or killed; the evolution of gas forms large subcutaneous and also deep-seated blowholes, but an ingot of such a steel contains no large contraction cavity or pipe. Also, the axial segregation is less pronounced than in either *killed* or balanced ingots. In general, this evolution of gas can be prevented by the addition of a small amount of aluminium or other suitable deoxidant. (I. 78.)

Rising Top. (See CAULIFLOWER TOP.)

Rist Technique. A method of studying inclusions in areas of a centimetre square or less on radial bands under a magnification of × 18. Areas are classified in accordance with the largest dimensions of the elongated inclusions or of the rows of inclusions. (C. 17.)

Rivet. A short bolt or shank used for fastening together two pieces, e.g. steel plates. It is inserted into a hole drilled through the two pieces and the joint is made tight and permanent by forming a head on each end of the projecting shank by hammering.

Rivet Test. A test which demands (*a*) that the shank shall be bent through an angle of 180° in the cold without showing signs of fracture on the outside of the bend, and (*b*) that the head shall withstand being flattened whilst hot to 2½ times the diameter of the shank without cracking at the edges.

R.K. Process. A method for converting pig iron into a product with a low carbon content, which is suitable as a substitute for steel scrap for remelting in steel furnaces. The iron tapped from the blast-furnace is granulated in the molten condition. The granulated iron is fed continuously into a rotary furnace, where it is decarburized without melting, in a gas mixure containing carbon dioxide and carbon monoxide in suitable proportions. Decarburization down to very low carbon contents is possible. (K. 4.)

rms. Abbreviation for root mean square value.

Rn. Chemical symbol for *radon.*

Roaks. (See ROKES.)

Roasting. The heating of iron ores prior to smelting in order to expel the moisture and reduce the sulphur content.

Robert Converter. A modification of the *Bessemer* converter. It was D-shaped in horizontal section with the tuyeres placed in a row along the flat side and inclined, so that the air on entering imparted a swirling motion to the metal in the converter. (G. 4.)

Roberts-Austen, Sir William Chandler, K.C.B., D.Sc., F.R.S. (1843–1902.) Professor of Metallurgy, Royal School of Mines, and Deputy Master of the Mint. He took an active part in developing the *iron-iron carbide diagram* and is particularly remembered for his work in connection with the Alloys Research Committee of the Institute of Mechanical Engineers, and for his researches on pyrometry and diffusion of solid metals.

Robertson Bar-Straightening Machine. A machine in which, by virtue of the variable roll angle, bar material of high or low tensile strength can be straightened without the necessity of changing the rolls. The machine is made in three standard sizes of a capacity from 0·125 in. to 4·0 in. in diameter.

Robertson Brittle Fracture Test. The specimen contains a stress concentrator composed of a nub on the side of the plate with a 1-in. diam. hole where liquid nitrogen is used as coolant. Heat is applied on the opposite side of the plate to establish the desired gradient across the specimen. A sawcut is made on the inside of the hole. The plate is loaded through end connections of thinner plate so that they are stretched beyond the yield point during the test. When the desired temperature gradient and stress are applied to the plate, an impacting device is directed at the outer surface of the stress concentrator nub which results in a brittle crack starting at the sawcut and propagating across the plate, the length of the crack thus produced depending upon the temperature gradient and the

average stress level, as well as on the quality of the plate tested.

Robiette Process. A heat treatment process carried out in a substantially closed furnace, in which a fluid fuel is burnt to partial combustion with a gas containing 70% or more of oxygen to produce a non-oxidizing atmosphere. The treatment is effected continuously in the furnace through which the heating gas and metal are passed in opposed directions. The fuel and gas are partially burnt at the exit end of the furnace, and passed to the cooler, entry, end of the furnace and burnt to substantially complete combustion so as to preheat metal entering the furnace. (R. 32.)

Robinson and Rodger System. A method of obtaining sound steel by fluid compression of the ingot in the mould. The moulds are divided in the centre, a removable packing piece being placed between the halves of the mould. The packing piece is removed when the metal has set, and the mould is placed horizontally in the press, pressure being applied to the ingot at both ends. (C. 11.)

Röchling-Rodenhauser Furnace. An induction furnace in which both legs of the transformer are provided with secondary windings. These are surrounded by annular induction channels which are connected with a central channel. (B. 23.)

Rochon Prism. This consists of two rectangular prisms of *calcite* cemented together to form a rectangular block, and designed to produce two widely separate images of a single object.

Rock Candy Fracture. An American term for a peculiar fracture noted in cylindrical bodies and hemispherical ends of forged cylinders for containing compressed air. Hydraulic tests cause rupture at unexpectedly low pressures, and the fractures exhibit matte, granular, or faceted surfaces. Part of the fractured surface is seen to have the conchoidal, rock candy, appearance. Test specimens cut from such material frequently show tensile strengths of half the normal value, whilst the ductility, as measured by elongation and Izod impact value, is reduced almost to zero. (L. 50.)

Rocker. A defect in a rolled sheet caused by uneven heating prior to rolling, when, owing to the difference in elongation on opposite sides, the work will curve sufficiently to form a rocker, the cold side being innermost.

Rocking Shear. An improved type of guillotine shear that uses a curved blade and a rocker movement to cut across metal. (A. 27.)

Rockrite Process. (*Compression Forming.*) In this process, tubing is produced by using semi-circular grooved dies that rock backwards and forwards over the tube, thus compressing the metal of the tube against the mandrel. Cold-reduction operations are carried out in three separate stages, and between the first and second, and the second and third stage, the tubes are given a stress relief anneal. (K. 8.)

Rockwell Hardness Test. In this test an indenter, either a steel ball or a diamond cone, known as a *Brale*, is forced into the surface of the test piece, first under a preliminary load and then under an additional load. On removal of the latter load, the permanent depth of the recovered indentation is measured and this is related to the Rockwell Hardness Number. In practice, the Rockwell hardness is read directly on the scale of the instrument, the red scale being used for ball indentations and the black scale for diamond indentations. There are two sizes of the instrument (i) the standard machine and (ii) the Rockwell *Superficial Hardness Tester* which operates on much smaller loads than for the standard machine. The Brale diamond is ground to an included angle of 120° with the point rounded to a radius of 0·2 mm. There are numerous scales according to the magnitudes of the total loads and to the type of indenter used. For the standard instrument the preliminary load is 10 kg. and the following scales are used (Br indicates diamond Brale and where a steel ball is used the diameter is indicated).

Scale	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*K*	*L*	*M*	*P*	*R*	*S*	*V*
Total load in Kg. Indenter	60 Br	100 1/16"	150 Br	100 Br	100 1/8"	60 1/16"	150 1/16"	60 1/8"	150 1/8"	60 1/4"	100 1/4"	150 1/4"	60 1/2"	100 1/2"	150 1/2"

For the Superficial Hardness Tester the preliminary load is 3 kg. and the scales used are:

Scale	15*N*	30*N*	45*N*	15*T*	30*T*	45*T*
Total load Kg. Indenter	15 Br	30 Br	45 Br	15 1/16"	30 1/16"	45 1/16"

Rockwell Superficial Hardness Tester. (See ROCKWELL HARDNESS TEST.)

Rod Crack. A longitudinal flaw formed in *wire rod* or wire, which has been caused by faulty rolling technique.

Rod Feeding. A method sometimes used in the casting of large sections. It consists in moving an iron rod up and down in the feeding gate after the metal has been cast. This movement retards solidification in the *gate* and allows the molten metal to feed down as the casting contracts on cooling thus preventing contraction cavities.

Rod Mill. (*a*) A rolling mill for the production of metal rods. (*b*) A mill for fine grinding, somewhat similar to the *ball mill*, but employing long steel rods instead of balls as the grinding medium. (A. 27.)

Rod Test for Temperature. A practical test for determining whether a heat of open hearth steel is hot enough for tapping. One end of a low carbon bar is held beneath the surface of the bath until it has melted off, the condition of the bath being judged by the appearance of the melted end of the bar.

Rodding. Reinforcing the sand in a core with metal rods or shapes to strengthen parts of the core. (A. 26.)

Rodenkirchen-Steel Casting-on Process. A composite casting process in which an attempt was made to achieve a bonding between bronze and steel by casting molten steel round the cold or slightly preheated bronze bearing shell. The chief difficulties encountered in this process include the care necessary to ensure uniform heating and cooling in all parts of the casting. In addition, because of the high melting point of the steel, it was not always possible to avoid a partial melting of the bronze layer. To avoid this, the casting temperature of the steel was lowered. This in turn necessitated changes in composition which reduced the mechanical properties, and the results obtained were unsatisfactory. (S. 31.)

Roeckner Tube Rolling Mill. A machine for the rolling of large pressure vessels. Roll pairs of special shape grip the walls of the hollow billet at equal distances round the periphery. As the rolls and billets revolve, the metal is rolled down to the desired thickness, and the rolls are so designed and adjusted that the tube, as it is formed, travels along on its own axis. (S. 42.)

Roederer Process. (See R.R. FULL FIBRE PROCESS.)

Roheisenzunder Process. (*RZ* or *Oxidized Pig Iron Process.*) A method which makes use of an air stream at a pressure of 4 atm. for atomizing molten pig iron into minute particles. The molten metal falling into an air stream formed by an annular slit in a steel cyclone is atomized, the particles falling into a water bath and subsequently dried.

Rohn Creep Test. The test-piece, in the form of a rod or wire about 1 m. long, is suspended in a vertical electrical-resistance-tube furnace, wound so as to give a uniform temperature throughout as much of its length as possible. Suspended from the same support, but situated entirely outside the furnace, is a frame, made from a low thermal expansion steel, the lower cross-piece of which carries an electric contact immediately below another such contact affixed to the lower end of the test-piece. Any desired load is applied to the lower end of the test-piece. On heating up, the test-piece lengthens, even if no stretching by the load occurs, until the contacts meet; this brings a relay into operation, and the heating current is partly or completely cut off. The test-piece now cools and contracts until the contact is broken, when the heating current is switched on again and the cycle is repeated. The test-piece itself thus acts as a thermo-regulator and maintains the furnace at a constant temperature so long as no stretching of the test-piece occurs. If the conditions of load and temperature exceed the *creep limit*, then elongation will take place, and the temperature of the furnace will fall until creep no longer persists. (M. 129.)

Rohn Furnace. A low-frequency induction furnace. An example of this type of furnace installed by Krupp had a hemispherical bath, of 1½ tons capacity which enabled even solid charges to be melted. It was wired for 2800 kVA, 220 to 240 V. 50 cycles, 3-phase A.C. (B. 95.)

Rokes. (*Roaks.*) Defects on the exterior of steel bars consisting of fissures elongated in the direction of working, which have been only partially closed up during rolling; their surfaces being separated by a thin film of scale. They originate from *blowholes* formed immediately below the surface of the ingot which have been broken down during forging or rolling and become oxidized.

Roll Barrel. (See ROLLING MILL.)

Roll Camber. The deviation of a roll from a perfect cylinder.

Roll Coating. Finely divided particles of the metal being rolled or of the oxides of that metal, which have adhered to the surface of the rolls during the rolling operation.

Roll Cogging. The rolling down of ingots in a *cogging mill.*

Roll Compacting. In powder metallurgy, the progressive compacting of metal powders by the use of a *rolling mill.* (A. 27.)

Roll Force. (*Rolling Load.*) The total vertical force exerted by the rolls in causing deformation of the material during its passage through the rolls.

Roll Forging. (*a*) A process of using steel rolls and hydraulic pressure to convert prefabricated steel billets into rings. The billets are first hammer forged into steel cylinders with central apertures so that they can be mounted on a mandrel and so roll forged. The press essentially comprises two hydraulic rams, on which the ends of the mandrel are respectively mounted, and its purpose is to maintain contact between the heated-steel cylinder and an overhead roller assembly while the cylinder is being rotated. The cylinder is rotated slowly at first to true its inner and outer surfaces. Then, as its wall thickness is reduced, rotations are accelerated until the cylinder attains the desired ring dimensions. (W. 22a.) (*b*) A process of rolling cutlery blades which has to some extent superseded hammer forging. It is effected by means of two pairs of mating dies, which are inserted a few inches apart in a pair of rolls from which they project slightly. The die surfaces are not quite parallel to the roll surfaces and are so ground that the space between each pair of dies decreases from front to back and from one side to the other. In carrying out the rolling process, the blade portion of the heated stamped blank is placed between the rolls and given one pass between the first or *mooding* dies which elongate it and impart to it a slight taper towards point and edge. This is immediately followed by two passes between the second pair of dies, called *plating* dies, which further elongate and reduce the thickness of the blade and give it the final, more pronounced taper from bolster to blade point and from back to cutting edge. (J. 3a.)

Roll Forming. An operation used in forming sheet. Strips of sheet are passed between rolls of definite settings that bend the sheet progressively into structural members of various contours sometimes called *moulded sections*.

Roll Gap. The space between the rolls, when there is no material in the rolls. Ideally, it is the vertical distance between the rolls at exit, and equal to the exit thickness of the strip.

Roll Housings. (See ROLLING MILLS.)

Roll Knobbling. (See SPELLERIZING.)

Roll Lathe. A lathe in which rolls are turned or dressed, i.e. machined to the desired shape.

Roll Life. The tonnage that has been rolled by the roll before it is scrapped.

Roll Marks. (*Roll Pick Up.*) Defects which appear at periodic intervals on the surface of a rolled product, and are caused by an imperfection on the surface of the rolls or to particles of matter picked up by the rolls.

Roll Necks. The end parts of the roll which rotate within the bearings. They are always smaller in diameter than the *roll barrel*.

Roll Over Machine. A moulding machine in which the *mould* is rolled over before the *pattern* is withdrawn.

Roll Pass. (See PASS.)

Roll Pick Up. (See ROLL MARKS.)

Roll Pressure. (*a*) Normal roll pressure. The radial pressure, at any point in the arc of contact, necessary to cause compression of the material at that point. The pressure varies along the arc of contact from entry to exit. (*b*) Mean roll pressure. The average value, taken over the arc of contact, of the vertical component of the normal roll pressure.

$$\text{Mean roll pressure} = \frac{\text{Total roll force}}{\text{Area of contact between roll and strip.}}$$

Roll Scale. Oxide of iron which forms on the surface of steel while it is being heated and rolled. Much of the scale is cracked and loosened during the rolling operation and may fall off the piece naturally or be blown off by high-pressure water sprays or other means.

Roll Spot Welding. The process of making separated *spot welds* with circular electrodes. This may be carried out with a seam welding machine by suitably adjusting the speed of the circular electrode and by interrupting the electric current. The space between the spots can be varied by adjustment of the timing mechanism. The process is used when water or gas tight seams are not required. (S. 103.)

Roll Spring. The sum of the deformations which ensue as a result of the rolled steel passing between the rolls. It exerts great force trying to separate the rolls. As a results the rolls deflect as do the bearing screws and housings.

Roll Surface Pyrometer. (See LEEDS NORTHRUP ROLL SURFACE PYROMETER.)

Roll Table. (See ROLLER TABLE.)

Roll Threading. (See THREAD ROLLING.)

Roll Torque. The total turning moment which must be applied to the rolls to turn them against the resistance to deformation of the material.

Roll Welding. A forge welding process in which the parts to be welded are brought to a suitable temperature and the weld is completed by pressure applied by means of plate rolls. This method is commonly used in the *cladding* of steel. (A. 37.)

Roll Wobbler. (See ROLLING MILLS.)

Rolled Edge. The edge of strip material which has been precisely contoured by the application of vertical as well as horizontal rolls.

Rolled-in Scale. A surface defect caused by scale, formed during a previous heating, which has failed to be eliminated during the rolling operations. It is one of the most prevalent surface defects.

Roller. (*a*) In rolling mill terminology, a part of a roller table which transports steel from stand to stand as contrasted with a roll which is a part of a stand of rolls. (*b*) The term applied to the man in charge of the actual rolling.

Roller Analyser. An apparatus using a gas elutriation method for the fractionation of powders and determination of particle-size distribution. Separation of fractions is effected by an air or gas stream of controlled velocity, passing upward through a metal settling chamber. Those particles which are too small to settle against the upward velocity of the gas are floated out of the chamber and collected in a porous paper thimble. Dispersion is accomplished by means of a nozzle through which the gas enters the sample tube under pressure. Oscillation of the sample tube forces the powder continuously toward the nozzle, creating an effective dispersion action.

Roller Flattening. (See ROLLER LEVELLING.)

Roller Guide. (See GUIDES.)

Roller Hearth Furnace. A continuous type of heat treatment furnace. One such furnace, used for annealing of steel sheet, is 5 ft. 6 in. wide by 70 ft. long and is equipped with a 20 ft. charge table and a 40 ft. discharge table. The hearth of the furnace consists of patented silicon carbide rollers which are externally driven in order to convey the work through the furnace. The steel furnace casing is provided with panels on both sides for removal of the rollers and the refractory radiant tubes. (I. 11a.)

Roller Levelling. (*Roller Flattening.*) A method of *flattening* sheet or strip in which it is given a number of flexures by being passed between an upper and lower train of rolls which are staggered and meshed slightly so that the sheet cannot proceed without flexing first one way and then another. The sheet is thus *cold worked* but not reduced in thickness.

Roller Stamping Die. An engraved *roller* used for stamping designations and markings on either circular or flat work. (A. 27.)

Roller Straightening. A process involving a series of staggered rolls of small diameter, between which rod, tubing and shapes are passed for the purpose of *straightening*. The process consists of a series of bending operations. (A. 27.)

Roller Table. This consists essentially of powered rollers set horizontally and parallel in a substantial framework for the purpose of conveying the metal between passes through the rolls.

Roller Twist Guide. (See GUIDES.)

Rolling. (*a*) The process of shaping steel by passing it between two rolls revolving at the same peripheral speed and in opposite directions. (See ROLLING MILLS.) (*b*) An operation similar to *tumbling* in that the metal parts and abrasives are loaded in a barrel or similar mechanism, but differing in that the work and abrasives are rolled in such a way that the load rolls over and over upon itself in a continuous flowing motion in relation to the rotating barrel. Rolling removes flash, rough spots and scale, and cuts down a metal surface to an even and uniform condition.

Rolling Friction. The term used when a body rolls on a surface as opposed to sliding over it. The law governing rolling friction is different from that of static or sliding friction, and if W = the total weight of the rolling body plus the pressure imposed on it in pounds and r = radius of the rolling body in feet, and μ r = the coefficient of rolling friction, then resistance to rolling in pounds $= \frac{W \times \mu r}{r}$. The coefficient of rolling friction varies with the conditions of the surfaces in contact; for instance, iron on iron may vary between 0·002 and 0·005 according to the degree of hardness, grade of smoothness and type of lubricant used. (S. 84.)

Rolling Hardness Tester. In this test, a ball 2·5 mm. in diameter is moved over the specimen under a constant load of 80 kg. The machine is designed so that the speed of the ball can be controlled within the range of 0·2 to 1000 mm./sec. and track lengths up to 100 mm. can be made on the specimen. The width or depth of the track is measured, and this is converted to *Brinell hardness* units by a calibration curve. (H. 32.)

Rolling Load. (See ROLL FORCE.)

Rolling Mills. In its simplest form, the rolling mill consists essentially of two horizontal rolls, mounted one above the other, revolving at the same speed, but in opposite directions so that the metal is drawn between them, this operation

(Reproduced by courtesy of Shepcote Lane Rolling Mills Ltd.)

Plate XIII.—A four-high cold reversing mill for the production of cold rolled stainless steel strip.

To face page 3[illegible]7

not only working the material to the desired shape, but improving its mechanical properties. The action of rolling tends to separate the two rolls, but these are held in a fixed position by means of the *chocks*, *housings* and *housing adjusting screws*, i.e. the *screw-down gear*. The rolls may be made of steel or cast iron. Steel rolls may be cast or forged and may be straight carbon or alloy steel in each case. Cast iron rolls may be alloyed or non-alloyed and may be chilled to give a hard working face. Rolls vary in diameter from ½ in. to over 4 ft. For the rolling of plate, sheet and strip, rolls are approximately cylindrical in shape with a plain surface, but for the production of bars, rails, structural shapes or sections, grooved rolls are used so that by passing the material through successive grooves the desired shape is attained. The middle portion of the roll, i.e. that part which is in contact with the material being rolled and which does the actual work, is known as the *barrel*. At each end is the *journal* or *neck* by which the roll is supported and at the end of either or both journals is a prolongation known as the driving end (*palm end*, *tenon end*, or *wobbler*), by means of which the roll is driven. The wobbler types of driving end may vary in shape, some being square and some cruciform in section. The wobbler is connected by the *coupling box* to the *spindle* which is the shaft or coupling by which power is transmitted to the rolls. The rolls are mounted in *housings*, two to each stand of rolls. These housings may be either of cast iron or steel but must be of substantial proportions and bolted to the mill bedplate. The journals revolve in bearings mounted in *chocks* which are fitted into openings in the housings, these openings being known as *windows*. The main types of mill bearings are (*a*) grease lubricated white-metal or bronze bearings, (*b*) precision-made white-metal bearings with oil flood lubrication, (*c*) compressed wood or synthetic bearings flooded with clean water, (*d*) roller bearings which are usually grease lubricated. In some mills (*cluster*) the work rolls are supported by *back-up rolls* and do not have journals or bearings. Rolling mills vary considerably in design. A *two-high mill* contains two horizontal rolls, one above the other. In some two-high mills the direction of rolling can be reversed, and these are known as *reversing mills*, i.e. when a piece has passed through the rolls, the rolls are stopped and then rotated in the opposite direction, thus imposing another *pass* on the steel, the operation being repeated until the desired reduction is attained. Between passes, adjustment is made to the height of the top roll, and/or the piece is moved sideways by means of manipulators, to be in line with other grooves in the rolls. A *pull-* or *drag-over-mill* is a two-high mill in which the piece is rolled in one direction only, and after travelling between the rolls has to be passed back over the top roll for re-rolling. A *three-high mill* consists of three rolls arranged horizontally, one above the other, each rotating continuously in one direction only, the piece being rolled between the bottom and middle, and middle and top rolls alternately. *Universal mills* usually incorporate, in addition to horizontal rolls, one and sometimes two pairs of vertical rolls. The horizontal rolls may be two-high or three-high and when two-high are usually arranged to be reversing. *Planetary mills* are used for making very large reductions on slabs by one pass through the mill. The mill consists of two large plain rolls, each surrounded by many small work rolls. *Jobbing mills* deal with a large number of small orders, and a *Merchant mill* usually rolls large quantities per size. A *four-high mill* (See Plate XIII, facing page 357) contains four rolls arranged horizontally, one above the other, i.e. two small diameter *working rolls* supported by larger diameter *back-up rolls* above and below. *Working rolls* are relatively slender and are driven, whilst the back-up or *idle rolls* are larger and are used to support the working rolls. Mills of this type are used for the hot and cold rolling of strip and may consist of one stand, usually reversing, or of several stands in tandem to form a continuous mill. A *Lauth mill* has three rolls, the middle roll being much smaller than the other two. The two larger rolls only are driven, work being performed between the bottom and middle and middle and top rolls alternately; the roll setting is adjusted between passes. A *Double-Duo mill* has two pairs of rolls, mounted in one stand, one pair of rolls being higher than, and in advance of the other. A *cogging mill* is usually a two-high reversing mill consisting of two rolls, 2 to 4 ft. in diameter, between which the hot ingot is reduced to *blooms* or *slabs*. (See Frontispiece.) A *continuous mill* (or *tandem mill*) has several stands set in series or in tandem, the first part of the bar or strip entering the second stand before its end has left the first. Continuous mills are usually of the four-

high type for the production of strip, and two-high for billets and bars. In some of the stands the roll axis may be vertical, instead of horizontal. A *semi-continuous mill* is one which incorporates some stands in tandem, either for roughing or finishing, an example being a semi-continuous wire rod mill with a continuous roughing train and a looping finishing train. A *looping mill* consists of one or more trains of alternating two-high stands. As the piece being rolled emerges from one stand, it is turned through 180° and entered into the next stand and similarly into the succeeding stands. In some mills the looping is performed by hand, whilst in others it is done mechanically by means of *repeaters* or *looping channels*. In a *hand mill* the bar is gripped at one end by means of tongs and held up during its passage between the rolls. In a *guide mill* this function is performed by *guides*. *Cluster mills* comprise two rolls of small diameter (*working rolls*) supported by two larger rolls (*back up rolls*) above and two below, i.e. six rolls in all. This design greatly increases the arc of contact with the metal being rolled, and thus effects a much greater reduction at each pass. They are used in cold rolling. In the *Sendzimir mill* the principle of the original cluster mill is further developed. (See Fig. 9.)

Rolling Off. In drop forging, the removal of the sharp edges of the die impression in order to facilitate the flow of the metal.

Rolling Over. The operation of reversing the position of a *flask* in which the drag part of the *pattern* has been rammed with the *parting* surface downward. (A. 26.)

Rollover Board. A wooden or metal plate on which the pattern is laid top face downward for *ramming* the *drag* half of the mould, the plate and half mould being turned over together before the joint is made. (A. 26.)

Rollover Machine. A moulding machine by which the *flask* is rolled over before the *pattern* is drawn from the mould. (A. 26.)

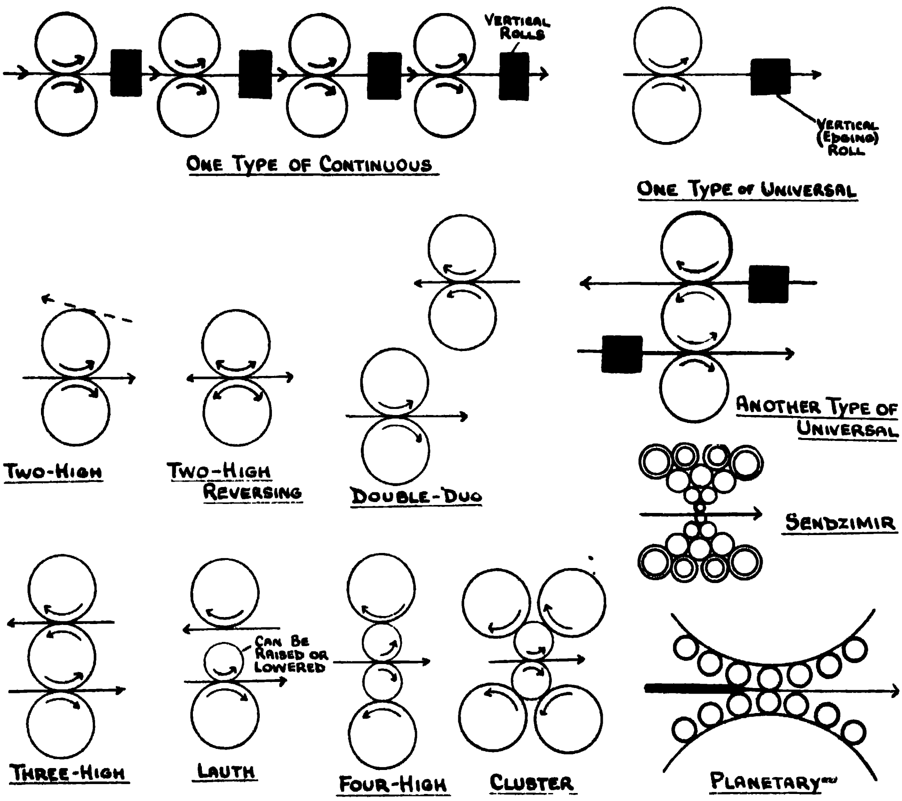

Fig. 9.—Some typical roll arrangements.

Rolls. (See ROLLING MILLS.)

Röntgen. A unit of measure of the amount of radiation (rather than intensity, which is the amount per unit of time).

Röntgen Rays. (See X-RAYS.)

Röntgen, William Konrad von. (1845–1923.) A German physicist, and the discoverer of *X-rays.*

Röntgenometer. An instrument for measuring the intensity of *X-rays.*

Root. (*a*) The zone at the bottom or inmost part of a space provided for or occupied by a fusion weld. (*b*) The bottom of a notch or crack.

Root Bend Test. A test for revealing lack of penetration at the bottom of a weld, the test specimen being bent in such a manner that the bottom of the vee of the weld is stretched.

Root Crack. A crack in the weld or base metal occurring at the *root* of a weld. (A. 37.)

Root Edge. The sharp edge at the root of an unchamfered or a full-chamfered fusion weld. (B. 105.)

Root Face. The unbevelled portion at the root of a partial-chamfered fusion face. A root face is usually small in depth. (B. 105.)

Root Gap. (See ROOT OPENING.)

Root of Joint. That portion of a joint to be welded where the members approach closest to each other. In cross-section the root of the joint may be either a point, a line or an area. (A. 37.)

Root of Weld. The points, as shown in cross-section, at which the bottom of the weld intersects the base metal surfaces. (A. 37.)

Root Opening. (*Root Gap.*) The separation between the members to be joined, at the root of the joint. (A. 37.)

Root Penetration. (See PENETRATION.)

Rooting. A defect occurring in steam pipes or boiler drums between the boiler scale and the steel casing which it attacks—working outwards and ultimately causing failure.

Roscoelite. (*Vanadium Mica.*) A vanadium ore containing up to about 28% of vanadium pentoxide.

Rosenhain, Walter, D.Sc., F.R.S. (1875–1934.) Born in Melbourne, Australia, he came to England as a research scholar and took up the study of metallography. A very large amount of research, especially in relation to the physical structure of metals and alloys and the mechanism of failure under stress is associated with his name.

Rosenhain and Haughton Reagent. An etching reagent for mild steel, having the following composition:

Ferric chloride	30 gm.
Hydrochloric acid (conc.)	100 ml.
Cupric chloride	1·0 gm.
Stannous chloride	0·5 gm.
Water	1 litre

(R. 40.)

Rosenholtz Smith Apparatus. (See DILASTRAIN METHOD.)

Rose's Metal. A low-melting point alloy containing approximately 50% bismuth, 28% lead and 22% tin; it melts at 96° C. (See FUSIBLE ALLOYS.)

Rosette. (*a*) A rounded configuration of eutectiferous constituents in the microstructure of an alloy. (*b*) Strain gauges arranged to indicate at a single position, strains in three or more different directions. (See STRAIN ROSETTE ANALYSIS.)

Rosin. A vegetable *resin;* the molten resinous residue remaining in the still after the distillation of spirits of turpentine from crude turpentine obtained from living pine trees. The molten resin is strained, and solidifies to form a solid rosin.

Rosival's Method. A method of determining hardness which depends on the loss in weight of the sample under test after grinding for a predetermined time with a predetermined weight of alumina powder.

Rossi Process. (See JUNGHANS-ROSSI CONTINUOUS CASTING PROCESS.)

Rossite. ($CaV_2O_6.4H_2O$.) A vanadium ore.

Rosslyn Metal. Copper sheet, clad on each side with thin gauge stainless steel. The sheets are forced together under pressure and the edges welded. This material is claimed to have high heat conductivity.

Rotary Bending Fatigue Test. In this type of test the maximum bending stress occurs in the surface layer of the specimen. One revolution of the specimen is equivalent to a complete stress reversal when loaded. The two most commonly used machines for carrying out rotary bending fatigue tests are of two simple and economical types: (i) The *Rotating Cantilever* type of machine consists of a motor which drives a chuck at a suitable cyclic speed. This in turn grips one end of a round test piece at the free end of which a load is applied suspended on a self-aligning ball race. The bending moment in this test varies linearly over the parallel portion of the specimen, and the applied stress is calculated at the critical section of the specimen. The number of reversals before fracture is determined by means of a revolution counter, geared to the shaft of the machine. (ii) The *Rotating Beam* type of machine consists of a composite beam, the centre portion of which consists of the test piece with a suitable parallel portion. The beam is

rotated by a motor as before and the load is suspended on two ball races equidistant from the end supports, which are free to swivel in a vertical direction. This method of applying the load to the specimen is referred to as four-point loading, and the parallel portion of the specimen is subjected to a uniform moment of pure bending throughout. The number of reversals are again measured by a revolution counter. (B. 3.)

Rotary Broaching. The method incorporates the principles of milling and broaching, making use of a revolving radial type cutter with step-up type teeth. (C. 43.)

Rotary Forming. Producing contours by rotating a forming die against material held under tension, or by forcing the material against a rotating die. There are three principal methods of working: stretch-forming, compression-forming and radial draw-forming. In *stretch-forming*, the forming-die is mounted on the table and one end of the material is held by table-mounted grippers. At the opposite end it is held by grippers on the hydraulic ram. Tension is first applied to the material and automatically maintained while the table is revolved, wrapping the part to be formed round the die. In this condition, the metal is flowing practically cold and will form to size and shape with the minimum amount of spring-back. In this process, which might be termed tangent forming, the metal is formed only a few inches at a time as the forming die on the rotating table tangentially sweeps by the metal that is being stretched on to it. In *compression-forming*, the action of the ram is reversed to apply pressure instead of tension and the material to be shaped is compression-formed by either rolls or shoes. (See also ROCKRITE PROCESS.) *Radial draw-forming* makes use simultaneously of both the *stretch* and *compression* methods of forming. An additional hydraulic side-head is mounted adjacent to the rotary table and is used only for compression-forming. The material is held in tension between the hydraulic ram and the table which, in revolving, draws the material radially over the outer diameter of the forming-die on the table. Simultaneously, pressure is supplied radially from the side-head to give closer contact between the metal and the forming die. (A. 19a.)

Rotary Furnace. A reheating furnace having a circular refractory-topped hearth, and a continuous construction of multiple-sections, each of which is supported independently on a spider frame, rotating upon wheels. A charging door is provided through which the cold steel is mechanically and automatically placed upon the hearth by a charging machine. After moving approximately 345° through the hot furnace, the steel is mechanically removed through a discharge door by a similar remotely controlled machine. A baffle is provided between the charge and discharge doors, to prevent chilling of the heated steel by the cold charge. (K. 47.)

Rotary Impact Testing Machine. A machine capable of impact velocities ranging from 20 to 200 ft. per second and consisting of a 750 h.p. hydraulic impulse turbine with exciter generator. A wheel of 44 in. diam. with a pair of striking jaws attached is rotated at a desired speed. By means of a strong spring, a yoke is moved up, becoming engaged with the jaws and in turn striking a tup fastened to the specimen, thus producing the impact. (D. 54.)

Rotary Press. In *powder metallurgy*, a machine fitted with a rotating table that carries multiple dies in which a material is pressed. (A. 27.)

Rotary Rolling Mill. A mill used in the production of seamless steel tubes. The shafts of this mill, which drive the conical rolls, are in separated horizontal planes and are placed at an angle of 60° with the axis of the tube being rolled. Each shaft is powered with a separate motor, which provides peripheral roll speeds of 2400 ft. per min. In operation the conical rolls grip and spin the pipe, feeding it forward over a large mandrel, thereby effecting a decrease in the wall thickness of the pipe and an increase in the diameter. The length of the tube is substantially unchanged by the operation. The rolling action is quite similar to that which takes place in a tyre or ring rolling machine, except that in the rotary rolling mill a forward helical advance is imparted to the tube, which is supported on the inside by the tapered mandrel. (W. 74.)

Rotary Shear. A cutting machine with sharpened circular blades or disc-like cutters used for trimming edges and slitting sheet or foil. (A. 27.)

Rotary Swaging. A mechanical means of reducing the diameter of bars or tubes, or of pointing and shaping the ends of rods and tubes, by hammering the metal, using rotary dies. The required shape is cut into the striking face of the dies, which rotate during the process and, therefore, the form of the finished component must be cylindrical. Swaging imparts to components

the same benefits as those obtained in forging. Tensile strength and elastic properties of metals are said to be improved. (M. 84a.)

Rotating Beam Fatigue Testing Machine. (See ROTARY BENDING FATIGUE TEST.)

Rotating Cantilever Fatigue Testing Machine. (See ROTARY BENDING FATIGUE TEST.)

Rotating Load Fatigue Testing Machine. (See BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION ROTATING-LOAD FATIGUE TESTING MACHINE.)

Rotational Slip. A deformation process in crystals produced by the slipping of one part of a crystal on a neighbouring part, so that the two sliding atomic sheets are the densely packed planes, rotationally displaced about an axis normal to their plane to a new position where metastable equilibrium can occur. Evidence for the phenomenon is drawn from electron-diffraction photographs of cadmium iodide, graphite, copper, and silver and from microscopic examination of crystals such as *quartz* and *pyrites*. Other examples of rotational slip occur in the development of deformation bands and in the lattice deformation caused by unidirectional abrasion of a single crystal surface along a direction parallel to a densely populated plane. (W. 59.)

Rotoblast. A machine which uses the principal of controlled centrifugal force for its blasting power, instead of compressed air. The abrasive is fed to a rapidly rotating, vaned wheel from which it is thrown by intense centrifugal force at the target, or surface to be treated. Directional control of the abrasive stream is secured by determining the proper point at which the abrasive is fed to the vanes.

Rotodip. A method for cleaning, phosphatizing, and primer painting motor-car bodies. The cycle of operations is: cleaning by emulsion or alkali-type cleaner; cold rinse; hot rinse (60° C.); *bonderizing*; hot rinse (68° C.); final rinse with dilute chromic acid solution at 71° C.; thorough drying in an oven; cooling in air to painting temperature; dip priming; flash off and draining; and stoving. The body passes through the plant on a spit, which rotates as the work passes through the various tanks. (E. 12.)

Roto Finish. A *tumbling* method using special chips and chemical compounds. (C. 16.)

Rotogenerative Detection of Corrosion. A test based on the fact that it is possible to separate the small potential drop produced by the corrosion current from the potential of the specimen as a whole. This is accomplished by the use of a rotating cylindrical specimen, scanned by a fixed reference electrode located close to the surface of the corroding metal. The technique, in effect, generates an alternating current signal which is a reproduction of the potential gradients set up in the corrosion medium by the local-action currents. A series capacitance permits amplification of the alternating current component to the desired level. (M. 1.)

Rotor Process. (See GRAEF ROTOR, page 473.)

Rouge. *Ferric oxide* in a fine state of division, used for polishing.

Rough Turning. (*a*) Primary turning operation in which large depths of cut and feed are employed. (*b*) The removal of superficial defects in steel *billets*, *ingots* or *castings*, by turning them in a lathe.

Rough Weight. As applied to forging, the term refers to the total weight of steel required for the production of a forging. It includes the weight of the forging itself, and all scrap.

Roughing. (See COGGING.)

Roughing Hole. An American term for a pit used for the reception of slag.

Roughing Mill. A mill used for preliminary rolling. It usually consists of vertical edging rolls and horizontal reduction rolls.

Roughing Pass. The term applied to the first pass of the piece through the rolling mill.

Roughing Rolls. Rolls in a *roughing mill*.

Roughing Stand. A *roughing mill*.

R.O.V. Strong sulphuric acid.

Rovalizing. Various coating processes, all involving phosphate treatment; the term is incomplete unless the specific Rovalizing treatment is stated.

Rowett Fatigue Testing Machine. A hand-operated machine for the application of alternating torsion. One end of the specimen is in series with a weigh-bar whose stress strain relations have been previously obtained by statical loading experiments, the other end being attached to a lever the movement of which is restricted within any desired limits by means of suitably placed stops. With any set amplitude of the lever, the strain of the specimen can be measured by means of an *extensometer* and the accompanying torque assessed by measuring the strain of the weigh-bar using a second extensometer. (G. 36.)

Royal. A size of paper 24 in. × 19 in. for writing and 25 in. × 20 in. for printing. (See also BOOK SIZES.)

Royal Aircraft Establishment, Farnborough, Hants. A research establishment devoted to development in aeronautics, acting as adviser to the industry and the Service on all matters relating to aircraft and aircraft design problems.

r.p.m. Revolutions per minute.

R.R. Continuous Grain Flow Process. (See R.R. FULL FIBRE PROCESS.)

R.R. Full Fibre Process. (*R.R. Continuous Grain Flow Process.*) The invention of Roederer for forging crankshafts. In this method the shaft is forged one throw at a time and there is no gapping out; the bar is bent to form the crank and at the same time upset to form the webs. This means that the axis of the ingot is always at the centre of each section so that the surface layers of crank pins, journals, and webs are of sound material with a continuous grain flow. The initial rolled or forged round bar is smaller than that used in conventional methods. (C. 36.)

R/S Dilastrain Method. (See DILASTRAIN METHOD.)

R-S Hi-Head Process. A method of heat treatment which consists essentially in the use of an extremely high thermal head in multiple heating chambers through which the workpieces are rapidly passed by mechanical means. Uniform heating is attained, while surface scale, decarburization, and grain growth are controlled. (S. 141.)

R.S.J. Abbreviation for rolled steel joist.

Ru. Chemical symbol for *ruthenium*.

Rubidium. (*Rb.*) *Atomic weight* 85·48. *Melting point* 39° C. Boiling point 680° C. *Specific gravity* 1·53. A silvery-white metal which is readily volatile and decomposes water with the liberation of hydrogen. Many of the minerals in which it occurs, and many of its salts, are radio-active. It takes fire easily in air. Rubidium is used in the manufacture of *photoelectric cells*.

Rubio Ore. An iron ore, mined in Spain. It contains about 50% of metallic iron, the *gangue* being chiefly siliceous.

Rudge-Whitworth Pliers. A hardness testing instrument designed for workshop use. It took the form of a pair of nippers. The load was controlled by a spring arrangement which forced a hard steel ball into the surface of the specimen, e.g. sheet metal. On removal of the load, the indentation was measured under a medium power microscope.

Rudorff Process. (See SPARCATRON.)

Ruling Section. (*Equivalent Section.*) The term is used in many British Standards and the *limiting ruling section* is always expressed as the maximum diameter of round bar in which the specified properties may be produced in the steel concerned by the heat treatment specified. Since many parts at the time of heat treatment do not even approximate in shape to round bar, it is necessary to have some means of relating the rates of cooling of other shapes to their *equivalent sections* of round bar. The diameters of round bars, the centres of which would cool through a given temperature range at the same rate as the centres of rectangular or square sections bars of different sizes, have been calculated. Tables for converting the sizes of plates or rectangular sections into equivalent sizes of rounds for oil quenching or air cooling respectively are included in B.S. 970:1955.

Rumbling. (See RUMBLING MILL.)

Rumbling Mill. A machine, resembling a barrel, in which small steel castings are rotated, usually with some small sharp pieces of metal, thus removing adhering sand and polishing the surface of the casting.

Run. (See PASS.)

Run Down. (See RUNNING DOWN.)

Runner. (*a*) A channel through which molten metal or slag is passed from one receptacle to another. In a *casting* mould that portion of the *gate* assembly which connects the *downgate* or *sprue* with the casting. (*b*) (See UPHILL CASTING.)

Runner Box. A device for distributing molten metal round a *mould*, by dividing it into several streams.

Runner Extension. In a mould, that part of a *runner* which extends beyond the farthest ingate as a blind end. It acts as a trap since the first rush of metal along the runner will pick up any loose particles of sand or foreign matter and carry them into the extension and not into the mould cavity.

Runner Riser. A conventional runner, usually in the horizontal plane, which permits the flow of molten metal to the ingate and is large enough to act as a reservoir to feed the casting. (A. 26.)

Running Away. The escape of molten metal from the mould during casting.

Running Down. Melting iron in a cupola. The charge is *run down* when it is completely molten.

Running Out. An excessive increase in the size of wire during drawing, caused by abnormal wear of the die, i.e. *nonsizing*.

Running Stick. A round wooden rod used as pattern in forming a gate in a mould.

Runout. (*Bleeding.*) (*a*) A casting defect caused by incomplete filling of the mould due to molten metal draining or leaking out of some part of the mould

cavity during pouring. Bleeding is a term usually applied to a partial run-out caused by stripping the casting too soon from the mould or by removal of *runners* and *risers* before the metal has completely solidified. (*b*) The escape of molten metal from a furnace, mould or melting crucible.

Run-Out Table. In a rolling mill, a plane area at the receiving end, for holding rolled metal. (See HOT BED.)

Runway. A metal trough or channel along which a bar travels whilst being rolled. Usually fitted into rolling mills on the mill floor in order to ensure that the bars do not become distorted by fouling other machinery.

Rupture Stress. (*a*) In a stress-rupture high temperature test, the rupture stress is the load divided by the original area. (*b*) The stress given by dividing the tensile load at the moment of incipent fracture, by the area supporting that load.

Rupture Test. This test, which is sometimes called the *stress-rupture* or *creep-rupture test*, is identical with the *creep test*, except that the loads, and consequently the creep rates, are higher, and the test is carried to failure of the material. The apparatus for carrying out the rupture test is usually of the type employed for the creep test, except that a different instrument is used for measurement of the elongation. In the creep test, the total strain is very often less than 0·5%, while in the rupture test the total strain may be as much as 1% to 50%, or sometimes more, depending upon the material and conditions of test.

Ruptured Fibre Structure. (See RUPTURED METAL.)

Ruptured Metal. (*Ruptured Fibre Structure.*) Forging stock, particularly on very thin sections, that has been so severely worked that broken fibres occur in the metal.

Russian Iron. (See BLUE PLANISHED STEEL.)

Rust. A hydrated oxide of iron, mainly $2Fe_2O_3.3H_2O$, formed on iron by exposure to moisture and air. (See also SULL COATING.)

Rust Resisting Steels. (See STAINLESS STEELS.)

Rustanode. A zinc paint.

Rustless Process. A process for the manufacture of stainless steels in an electric furnace which uses a chrome ore as a source of chromium with or without the addition of silico-ferro-chromium, conjointly with stainless steel scrap. The hearth of the furnace is lined with chromite bricks. The hearth temperature is of the order of 1780° C. (J. 27a.)

Rustshield. A manganese-iron-phosphate coating for use on iron or steel.

Ruthenium. (*Ru.*) *Atomic weight* 101·1. *Specific gravity* 12·2. *Melting point* 2500° C. A hard brittle metal. It is added to palladium in amounts of about 4% as a hardener, thus giving the so-called jewellery palladium alloy. Platinum alloys containing about 10% ruthenium have been used for the manufacture of electrical contacts.

Rutherford, Lord. (Baron Rutherford of Nelson, F.R.S.) (1871–1937.) Born in New Zealand, Rutherford joined the Cavendish Laboratory, Cambridge, as a research student in 1895, where he began to study the radiations from uranium, later continuing these investigations as Professor of Physics at the McGill University, Montreal. With Professor F. Soddy, he put forward the theory of spontaneous disintegration of atoms of radioactive elements. He established the structure of the atom as consisting of a positive nucleus surrounded by negative electrons.

Rutile. A mineral containing titanium oxide (TiO_2). It is variable in composition and may contain up to 10% of ferric oxide. It is one of the main sources of titanium, but for the production of *ferro-titanium*, *ilmenite* is generally preferred, whilst rutile is used for the production of coated welding rods.

R.V. (*a*) Abbreviation for *Relative Volume*. (*b*) *Restriking Voltage*.

R.Z. Process. (See ROHEISENZUNDER PROCESS.)

S

σ. (See SIGMA PHASE.)

S. (*a*) Chemical symbol for *sulphur*. (*b*) British Standards relating to aircraft materials and components include an S series covering steels.

S and O. Abbreviation for *Sheared and Opened*.

S-Curve. (See TIME TEMPERATURE TRANSFORMATION CURVE.)

S/N Curve. *Stress-number curve* showing the number of reversals to rupture under a given applied stress in a *fatigue test*.

Sa. An alternative chemical symbol for *samarium*.

S.A.C. Test. (See BURNS AND RIEGELS TEST.)

Sach's Boring Method. A method of determining residual stresses in cylindrical metal bodies or thick-walled tubing in which a hole is drilled up the centre of the cylinder and the cylinder is then bored out in steps. The dimensions of the cylinder, i.e. external diameter and length are measured

accurately after each successive step in the machining operation and the residual stresses originally present in the cylinder are calculated from a series of given equations. (D. 38.)

Sach's Wedge-Drawing Test. A test devised to assess the *deep drawing* capacity of a metal. The lower and parallel end of the test piece is gripped in the bottom jaws of an ordinary tensile machine, whilst the upper end, which is tapered or wedge-shaped, is inserted into a chamber of similar shape, having three rigid faces and a fourth which can be adjusted to accommodate specimens of various thicknesses and to prevent buckling of the specimen. The top of the chamber is clamped in the upper jaws of the testing machine, and pressure is exerted upon the lower or parallel portion of the test piece until it has been drawn completely through the tapered die, or until rupture takes place in the parallel section. The ratio of width of the top of the taper to the length of the taper on a standard specimen at the greatest width of specimen which can be drawn through the die is termed the *deformation number*, and is used as a basis for comparison. (S. 28.)

Sack Mill. A mill having both horizontal and vertical rolls which act simultaneously. It is designed for rolling cruciform sections.

Sacrificial Coating. A coating used for *sacrificial protection*.

Sacrificial Protection. The property possessed by certain metals, e.g. zinc, of protecting iron or steel from rust although the coating may not completely cover the entire surface, any initial attack on small unprotected areas being protected from progressive attack by the products of corrosion.

Sadden. An operation in which an ingot is given a succession of light reductions under a hammer or press or in a rolling mill with the object of overcoming initial fragility due to coarse crystalline structure and endowing it with strong cohesion and toughness.

Saddle. A mandrel on which the pierced disc is placed in the operation of *saddling*.

Saddle Spring Wire. A high carbon steel wire used for bicycle saddles.

Saddling. The rolling of a pierced disc over a mandrel and forging it to produce a weldless rolled ring.

SAE. Society of Automotive Engineers. (U.S.A.)

SAE Aeronautical Drafting Manual. This manual covers the drafting practices of the aircraft-engine, aircraft-propeller, and aircraft-accessory manufacturers and airline operators, and contains sections on preparation of drawings, dimensioning by the decimal system, notes, abbreviations and symbols, definitions, threads, gears, splines and serrations, forgings, finish marks and special finishes, springs, and welding, plus tables of data useful to draftsmen, designers, and other engineers.

SAE/AIR. Society of Automotive Engineers, Aeronautical Information Reports, which contain engineering data of sufficient value to warrant publication but which do not lend themselves to the classification of standards or recommended practices.

SAE/AMS. Society of Automotive Engineers, Aeronautical Material Specifications, which are material and process specifications conforming to engineering and metallurgical practices in the aircraft industry.

SAE/ARP. Society of Automotive Engineers, Aeronautical Recommended Practices. Dimensional designs or performance recommendations based on sound engineering principles and intended as guides towards standard engineering practice.

SAE/AS. Society of Automotive Engineers, Aeronautical Standards. (1) Design standards conforming with established engineering practices in the aircraft industry; (2) parts standards conforming with engineering practices in the engine, propeller, accessory-equipment and airline industries; or (3) other aeronautical specifications that do not fall within the category of SAE/AMS.

SAE Automotive Drafting Standards. Part I includes sections on drawing forms, lines and line work, lettering, sectioning, projection, dimensioning, decimal dimensioning, limits and tolerances, screw threads, drawing revisions, layout forms, layout practice, and checking practice. Part II includes sections on castings, die castings, metal stampings, forgings, gears, splines and serrations, springs, plastics, powder metallurgy, surface finish, chassis frames, body outline and seating diagrams, placement of body draft views, body construction, body mechanisms, body silencing and sealing materials, abbreviations and symbols, and definitions and notes.

SAE Number. The code number used for specifications issued by the Society of Automotive Engineers.

SAE Specifications. A series of specifications issued by the Society of Automotive Engineers, Inc., 29 West 39th Street, New York 18, U.S.A.

Saeger Spiral. A spiral shape mould used for testing the fluidity of molten metals. The molten metal is poured into the mould under strictly specified conditions and the fluidity of the metal estimated from the length of the resultant frozen spiral.

Safe Edge. (*a*) The uncut edge of a file. (*b*) The unsharpened side of a blade.

Safflorite. A mineral consisting essentially of cobalt arsenide $CoAs_2$. Nickel and iron are also present in small amounts.

Sag. A decrease in metal section in a casting due to sagging of the *cope* or *core.*

Saggar. (*Seggar.*) A fireclay box in which pottery is packed to protect it from injury during firing. The use of the saggar has been extended to the protection of other fragile articles.

Sal Ammoniac. Ammonium chloride. (NH_4Cl.)

Sal Chalybis. Ferrous sulphate.

Sal Soda. Sodium carbonate.

Salamander. (See BEAR.)

Salford Hardness Tester. An instrument designed for measuring the hardness of metal sheets or foils of the order of 0·02 to 0·03 mm. in thickness. A load is applied to a steel ball $\frac{1}{16}$ in. in diam. through a spindle and the movement of the latter causes a movement of an iron core between two electro-magnets which are parts of a Wheatstone bridge. The bridge system becomes unbalanced and this is indicated by the needle of a galvanometer in the circuit which moves over a scale calibrated both in millimetres and in the Rockwell hardness numbers. The accuracy of the readings obtained varies between 2 and 5 Rockwell numbers. (S. 48.)

Salford Magnetic Sorting Bridge. An electronic device, used for comparing manufactured articles of ferrous metals with a master part or sample. It consists of two balanced coils and an amplifier with a cathode-ray oscillograph which portrays the hysteresis loop of the part under test. The apparatus has two objects; the first is to make sure that the part tested has the desired properties before any work is done on it and the second is to ascertain whether the properties have been altered by the process of manufacture. A master part with the desired properties is placed in one coil, and the part to be tested in the second coil. Differences in the properties are easily detected by changes in the shape of the loop. (E. 52.)

Salt. Any substance which yields ions, other than hydrogen or hydroxyl ions. A salt is obtained by displacing the hydrogen of an acid by a metal, or by neutralization of the acid with an alkali, or by double replacement.

Salt and Pepper Fracture. (See PARTIALLY GRAPHITIZED CAST IRON.)

Salt Bath. A bath of molten salts used for heating steel, e.g. for hardening or tempering. Different salts are used for different temperatures; for tempering, e.g. sodium and potassium nitrate; and for hardening, sodium cyanide and sodium, potassium, barium and calcium chlorides.

Salt Bath Brazing. In salt bath brazing the parts to be joined are machined to correct size limits, cleaned free from scale or grease, and the brazing alloy is placed in position. The assembly is warmed to remove moisture and then placed in the salt bath at the requisite temperature. The advantages claimed are: (1) Speed of operation and greatly reduced labour costs; (2) accurate temperature control; (3) the scale-free finish requires less work in finishing operations; and (4) several joints of a complicated assembly can be brazed simultaneously. Sodium cyanide baths can be used for brazing in the 650° to 950° C. range. (M. 122.)

Salt Bath Chromizing. A method of chromizing ferrous materials by immersion in fused salt baths containing from 5% to 30% by weight chromous chloride at a temperature of 900° to 1200° C. (C. 7.)

Salt Bath Furnace. A furnace designed to hold a bath of molten salt in which a steel part is immersed for heat treatment, brazing or the like.

Salt Patenting. A *patenting* treatment in which the cooling is commenced by immersing the piece in a bath of molten salt.

Salt Spray Test. A corrosion test in which specimens are exposed to a fog of particles of a 20% solution of sodium chloride at 32° C.; no spray impinges directly on the specimens. This test has been used for the evaluation of materials exposed to the atmosphere and for electrodeposited metal coatings.

Salt Water Plating. In this method the article to be plated forms the cathode whilst the anode consists of zinc, the plating bath itself generating the current. The zinc anode is immersed in a concentrated solution of common salt, and the cathode in an appropriate metallic solution. The two solutions are separated by a porous diaphragm and the electrodes are connected by a conductor.

Salzgitter Ore. An important iron ore deposit in Germany. It consists of

conglomerated oolitic *limonite* and contains about 30% iron.

Samarium. (*Sm* or *Sa.*) A metallic element belonging to the rare earth group. *Atomic weight* 150·43. *Specific gravity* 7·7. *Melting point* 1300° to 1400° C. It cannot be electrodeposited and has not yet found any commercial application.

Sample. That portion of a material selected for testing.

Sampling Spoon. A tool made from mild steel round bar, which is forged out to make the bowl and this is then welded on to the handle consisting of a long bar of mild steel. The sample is taken by drying the spoon in the furnace, coating with slag and then withdrawing a spoonful of metal from the *bath*.

Sand. (*a*) Specifically a loose material consisting of small but easily distinguishable grains, often of quartz, resulting from the disintegration of rock. When used as a moulding material the grains should pass through a No. 6 sieve and be retained on a No. 270 sieve. The name is sometimes applied to a sand clay mixture appearing naturally in proper proportions for moulding. (A. 26.) (*b*) A term sometimes applied to a coarse slag inclusion.

Sand Blasting. A method of cleaning metal surfaces by means of sand directed from a nozzle at high velocity; also used for forming a key on the surface of various materials requiring a finish such as enamel.

Sand Blow. (*Air Lock.*) A smooth depression formed on the surface of a casting, often caused by inadequate venting of the mould.

Sand Bobbing. A polishing process produced by the introduction of relatively coarse abrasives between the surface to be polished and a revolving bob.

Sand Buckle. A rough irregular projection on the surface of a casting. It is always loosely adhering and contains embedded sand. It is easily removed leaving a smooth depression in the casting. Sometimes called a *dumb*, *blind* or *ramming* scab. (I. 14.)

Sand Burning. The formation of a hard surface on a *sand casting* by the reactions between the sand of the *mould* and the hot metal. (A. 26.)

Sand Castings. Castings produced in *sand moulds*.

Sand Control. Procedure whereby various properties of foundry sand, such as fineness, permeability, green strength and moisture content, are adjusted to obtain castings free from blows, scabs, veins and similar defects. (A. 27.)

Sand Core. (*a*) (See CORE). (*b*) A type of core employed when hollow drill steel was first introduced. The hole in the billet was tightly packed with silica sand and at each end a plug was inserted and riveted over. After rolling, the two ends embracing the riveted areas were broken off and the sand cleaned out by means of a high-pressure water jet. The wall of the hole left in the finished drill rod by this method was always more or less roughened, and thus was often the cause of fatigue failure. (C. 28.)

Sand Crusher. A machine comprising a stationary cylinder into which the sand is charged. Inside this cylinder is fitted a main shaft on to which are bolted retaining discs whose main function is to prevent the loose ball in between each disc from travelling laterally. As the discs rotate on the shaft the lumpy sand is removed into contact with the balls which crush the sand to grain size.

Sand Cutting. Preparing sand for *moulding*, either by hand or machine, the operation also aerating the sand. (A. 26.)

Sand Galvanizing. A process of galvanizing wire in which the wire, immediately on emerging from the galvanizing bath, is passed through damp sand which removes any superfluous zinc.

Sand Holes. Cavities of irregular shape and size, the inner surfaces of which plainly show the imprint of a granular material. (A. 26.)

Sand Marks. Defects in the surface of steel caused by refractory material becoming embedded during rolling.

Sand Mixers. (See HERBERT'S DUPLEX SAND MIXER.)

Sand Mould. A body of sand surrounding a cavity for the reception of molten metal in the production of castings. The cavity must have dimensional accuracy and the sand surrounding it must be of sufficient stability to allow the metal to solidify in the exact shape of the impression. The production of the sand mould involves making a *pattern* of the part to be cast, packing moulding sand round the pattern, which when withdrawn leaves the cavity into which the metal is poured, *cores* being inserted to leave cavities where desired in the casting. The frame within which the mould is made is known as the *flask* and consists of at least two parts, the *cope* and the *drag*, any parts inserted between the cope and drag are called *cheeks*. A *bottom board* supports the sand. Alignment between cope and drag when the flask is closed, is obtained by means of *pins* or *lugs* attached to the flask. *Gaggers* hold up pockets of sand in the cope. The metal is melted

under controlled conditions in a furnace or *cupola*, and is then poured into the *pouring basin* provided in the mould and flows via the *sprue* along *runners* to the *ingate*. *Risers* allow the dissolved gases to escape and also provide a feeder reservoir during solidification. When the metal has solidified the casting is shaken out of its mould and the gates and risers are sawn off.

Sand Muller. A machine for mixing sand by a kneading and squeezing action.

•**Sand Reclamation.** The processing of used foundry sand, by thermal or hydraulic methods, so that it may be used in place of new sand without substantially changing current foundry practice. (A. 26.)

Sand Slinger. A machine used to throw sand into the *mould*. This is done with sufficient velocity to ram the mould and fill the *flask* rapidly.

Sand Tempering. Adding sufficient moisture to sand to make it satisfactory for moulding purposes. (A. 26.)

Sand Wash. Roughness on the surface of a casting; it appears in the form of a lump or pit, and is due to the dispersion of the sand by the inflowing hot metal.

Sandberg Sorbitized Process. The process consists of allowing a red-hot rail from the rolling mill to run under a quenching hood, where a very fine mist of cold water is deflected on to the top surface for a controlled time. The rate of quenching is low, and whilst most of the rail remains red hot for a considerable time, the top surface is black on leaving the hood. The Brinell hardness of the running surface of a rail so treated is raised from about 220 to 330. (O. 11.)

Sanding. A polishing process carried out by means of a hide wheel on to which is fed a suitable abrasive and a lubricant.

Sandontap Moulding. A plant for supplying sand to moulds, which consists of a battery of vertical hoppers to which the sand is fed by an overhead conveyor belt. There is an electrically driven blower at the base of each hopper. The delivery side of each hopper consists of an articulated tubular arm to which may be attached a long length of flexible tube. To mould, the delivery end of this tube is simply moved horizontally over the box until the stream of sand has filled it. It is claimed that a mould made with this equipment has a high degree of permeability and that the sand on a vertical surface is just as hard as on a horizontal one. (F. 34.)

Sands. In a crushed material, a size of particles that will settle easily in water. The particle size of sands is coarser than that of *slimes*. (A. 27.)

Sandwich Electrode. A welding electrode, the name "sandwich" being derived from the fact that two core wires of semi-circular section with an insulator between were used. Each core wire was connected to one pole of a two-phase circuit. Sandwich electrodes appeared in France, England and Holland, but were abandoned due to the inherent difficulties of manufacture and also because of their great heat input into the weld. The advantage of the higher deposition rate was out-weighed by increased distortion and the residual stresses in the workpiece. (L. 16a.)

Sandwich Rolling. The rolling of dissimilar metals together to form composite sheet. (A. 27.) (See CLADDING.)

Sandwich Weld. A method of *cold welding* in which the third piece of metal is sandwiched between the two workpieces, and all three welded together in a single operation. (D. 46.)

Saniter Process. A method developed by Saniter in 1892 for the removal of sulphur from the molten steel bath by the addition of fluorspar, adding about ½ ton to a 50 ton furnace as soon as the charge was melted. Frequent additions of limestone were then made to increase the basicity of the slag. (L. 12.)

Sankey Diagram. A means of presenting the results of a furnace heat balance. It consists of a two-dimensional map of the parts of a system on which is superimposed a stream representing the flow of energy. (T. 23.)

Sankey Machine. A hand-operated machine devised for the application of repeated stresses. A flat steel spring, one end of which is rigidly clamped in a vice, carries at the other end a holder into which the test piece ⅜ in. diam. and 4 in. long is secured. The further end of the test piece is fixed into the end of a long handle, which is bent backwards and forwards through an angle of 91½°. The bending moment exerted at each bending is measured by the spring and recorded autographically. (G. 36.)

Sap. The unaltered (i.e. uncarburized) centres of certain of the lower content grades of *blister bar*.

Saponification. The neutralization of a fatty acid by an alkali, with the formation of soap.

Saponification Number. The number of milligrams of potassium hydroxide required to neutralize all the acid in one gram of a fatty acid or other substance.

S.A.S.I. South African Standards Institution.

S.A.S.M.U.T.A. Sheet and Strip Metal Users' Technical Association.

Satin Finish. (*Butler Finish.*) The finish obtained by buffing with a suitable abrasive or by the use of a wire brush.

Saturated Compound. A compound in which all the valencies of the elements are satisfied.

Saturated Magnetization. That condition of a body when an increase in the magnetizing force produces no change in the intensity of magnetization.

Saturated Solution. A solution containing the maximum amount of a particular substance in solution that it can dissolve at that temperature.

Saturation. The maximum number of lines of force which can be obtained in an iron or steel core. Further increases in magnetizing force over that necessary to achieve this saturation flux density will not cause the generation of any additional flux within the core. Saturation in electrical sheets occurs at flux densities varying from about 21,500 gausses for low silicon steels to about 19,500 gausses for those with a high silicon content.

Saturation Induction. (See INDUCTION, SATURATION.)

Saunders-Roe Technograph Foil Strain Gauge. This gauge replaces the thin wire of the usual strain gauge by a grid of foil. The ends of the gauge can be soldered to the leads without difficulty, and the gauge can carry much higher currents than the wire gauge, thus providing greater sensitivity. The larger surface area gives greater heat dissipation, making it possible to dispense with amplifying equipment in certain applications. (A. 10.)

Saustein. Compact *limestone*.

Sauveur Overflow Method. The object of this process is the production of pipeless ingots; it consists in connecting a number of moulds so that the molten metal can overflow from one mould into the next while pouring is continued in the first mould. (S. 16.)

Saw Doctor. A highly skilled craftsman who tests and adjusts stresses or unevenness in the surface of band- and circular-saws.

Say Ladle. A small, long-handled ladle for sampling molten metal.

Sb. Chemical symbol for *antimony*, from the Latin *stibium*.

S.B.A.C. Society of British Aircraft Constructors, Ltd.

Sc. Chemical symbol for *scandium*.

Scab. (*a*) The lifting of a piece of a sand mould face due to the presence of gas or air in the facing sand during casting. (*b*) A rough area found on the surface of a casting. It is caused by a portion of the mould breaking away, and the cavity thus formed becoming filled with molten metal, which is frequently contaminated with sand. (*c*) (*Shell.*) A projection on the surface of an ingot caused by steel flowing into a cavity in the wall of an imperfect mould or by metal from the wall of the mould adhering to the surface of the ingot. (*d*) A defect caused by scale that has been rolled into the surface of the steel.

Scaffolds. A term applied to obstructions formed in the *blast furnace* which impede the regular and even descent of the charge. Scaffolds may consist of displaced brickwork behind which deposition of carbon has occurred and agglomerates of slag, coke, iron oxides and reduced iron together with alkali silicate compounds, adhere to the refractory wall. (C. 25.)

Scaife. A cast iron disc impregnated with diamond dust and olive oil which is rotated at high speed. It is used to flatten diamond dies.

Scaife Process. A modified *Ugine-Sejournet* process for hot extrusion of steel and other metals. The basic difference between the original Sejournet extrusion process and the Scaife modification is one of direction. In the Sejournet, the billet is forced forward through the die with the mandrel projecting through the die to maintain internal shape. In the modified process, the billet is forced into the closed die and the ram pressure squeezes it back over the mandrel. Both are based on the use of molten glass as a lubricant. (I. 40.)

Scale. The oxidized surface of steel produced during hot working or by exposure to air or steam at elevated temperature. It consists of partially adherent layers of corrosion products consisting of iron oxides in the form of FeO, Fe_2O_3 and Fe_3O_4. The scale becomes cracked and eventually breaks off during working and according to the operation is known as *roll-*, *hammer-*, or *mill-scale*.

Scale Breaking. Breaking up the coating of iron oxide on the surface of hot rolled strip by passing it through a mill in which it receives a series of reverse bends. The operation also serves to eliminate any tendency to kink during further manipulation.

Scale Breaking Rolls. A series of roll stands by means of which tubes are slightly compressed with the object of loosening the scale formed on the internal surface.

Scale Pit. A surface depression in a forging produced by *scale* in the dies during the forging operation.

Scale Test. (See HERBERT PENDULUM HARDNESS TEST.)

Scale-Tight Finish. A final coating on a steel surface that has received special treatment with the object of increasing its resistance to *scaling* or *spalling*.

Scale Work Hardening Test. (See HERBERT PENDULUM HARDNESS TEST.)

Scales. (*a*) The outer flat parts of a penknife. (*b*) (See SHELLS).

Scaling. The formation of *scale* on the surface of steel, but the term is sometimes used to describe the removal of scale, i.e. *descaling*, as in *pickling*.

Scalping. The removal of rough surface layers from ingots, billets and slabs, by machining, e.g. *milling*, or with pneumatic hammers (i.e. *chipping*).

Scandium. (*Sc.*) A metal belonging to the *rare earth* group. *Atomic weight* 44·96. *Specific gravity* 2·5. *Melting point* 1200° C. It cannot be electrodeposited and has found no commercial application.

Scantlings. (*a*) The dimensions used in a design in order to adapt it to the working conditions. (*b*) Certain sizes of building stones and of timber, respectively.

Scarabizing. A method of producing a rust resistant zinc coating on iron or steel.

Scarf. (*a*) To bevel the edges of *skelp* in the process of making *lap-welded* pipe. (*b*) To bevel the edges of plates prior to welding. (*c*) (See SCARFING).

Scarf Joint. A special form of butt joint in which the surfaces to be joined are cut at an angle less than 90°. It can be used where maximum strength without increase of material thickness is desired. With this type of joint, it is necessary to have close clearances to produce a high strength joint, and, in addition, the joint surfaces should be cut accurately to the angle specified.

Scarfing. A process of burning out defective areas on the surface of semi-finished steel, by the oxy-acetylene method. By this means, the surface of the steel is put into such a condition that it can be rolled or forged to a satisfactory product.

Scattering. The re-emission of X-rays from irradiated matter, without change of wave-length (except as modified by the Compton effect, which is negligible in crystal analysis); scattering takes place in all directions with respect to the incident X-rays, but more intensely (or more often) in some directions than in others. (A. 27.)

Scavengers. (See DEOXIDIZERS.)

Schaaber Etching Reagent. An etching solution for cast iron and steel structures which consists of a 1% to 3% solution of concentrated nitric acid in concentrated acetic acid. The specimen, ground and polished in the ordinary way, is washed with water, then in alcohol, dried in hot air, dipped in the etching solution for 5 to 30 seconds at room temperature, washed in running water, then in alcohol, and dried. It can be re-etched without repolishing. (S. 17.)

Scheelite. An ore of tungsten consisting essentially of calcium tungstate ($CaWO_4$). Molybdenum is usually present and may replace a considerable part of the tungsten. Part of the calcium is sometimes replaced by copper, when the mineral is known as *cupro scheelite*. Scheelite is one of the two most important commercial ores of tungsten. (Cf. WOLFRAMITE.)

Schenck Autographic Extensometer. An instrument for the measurement of the dynamic extension and compression in a member of a built-up structure or machine; in this way the stresses in the piece are determined and, by means of a time record, their amplitude and frequency can be worked out. In essentials, the instrument comprises two tubes, one sliding in the other; they are provided with hardened points which are pressed into the object under test. The points are usually 200 mm. apart. One tube carries a slowly rotating glass drum at its end on which a line is scratched by a diamond point fixed to the end of the other tube; a second diamond mounted on the first tube traces a circle to serve as a baseline, and also indicates periods of time through the action of suitable mechanism. (S. 11.)

Schenck Machine. A machine for determining the fatigue limit of metals in which the test piece is held between two jaws, one of which is twisted slightly by means of an arm attached to an eccentric; the throw of the latter can be accurately varied during the operation of the machine. A static torsional stress can also be superimposed on the dynamic stress. The second jaw is attached to a dynamometer, which follows the oscillating stresses in the test piece and indicates the smallest alterations. The rise of temperature of the test piece due to the internal work can be measured by a *thermocouple*, or, the specimens may be cooled by a stream of oil. For tests at high temperature provision is made for passing a current through the specimen itself. When the test piece breaks, the machine shuts down automatically; the number of load reversals is indicated on

a counter. Static torsion tests can also be carried out. (S. 10.)

Schlesinger Machinability Tester. A machine which rapidly measures the two basic characteristics of the machinability of a material. These are the specific cutting resistance, representing the work done by the tool on the material and the abrasive effect of the same material, representing the wearing effect of the material on the tool. It is claimed that the product of these two factors is a machinability index, which indicates the effort required to machine a given material and that it can be used to compare the relative machinability of various metals. (L. 27.)

Schliha Metal-Spraying Process. A process for the building up and reconditioning of worn parts. A special spray pistol is employed and the metal to be sprayed which may be steel, bronze, copper or aluminium, is fed automatically, in the form of wire, to the nozzle where it is melted by an oxy-acetylene or oxy-hydrogen flame and projected as a fine spray by means of compressed air at a pressure of 2·5 atmospheres. It is claimed that a layer of steel of any desired thickness may be sprayed on to a worn surface and that the coating is very firmly adherent and can be subsequently ground to size. (E. 42.)

Schnadt Notch Impact Test. This differs from the *Charpy test* by having the compressive zone of the specimen on the side opposite the notch removed by a drilled hole. Into this hole fits a hard steel mandrel round which the material is bent on impact. The test section is purely in tension, and complete fracture of the specimen is obtained. The fracture section is 3 × 10 mm. against 5 × 10 mm. in the Charpy test, the small depth permitting a more localized study of the material. Three types of test specimen are used: (1) a notchless specimen to obtain a bi-axial state of stress termed *Dynacité*; (2) a radiused notch specimen to obtain a tri-axial state of stress termed *Résilacie*; (3) a specimen with a very acute notch causing a severe tri-axial state of stress termed *Cohéracie*, this test reproducing practically the effect of a crack. (M. 172.)

Schoen Mill. A mill for rolling railway tyres in which the tread and flange of the tyres are rolled simultaneously with the web, whilst the forged tyre blank is rotated in a horizontal position. This is carried out by means of a pair of driven web rolls and an idler tread roll in simultaneous contact with the tyre blank. The width of rim is controlled by a pair of idler rim rolls.

Schofield-Grace Immersion Pyrometer. (*Quick Immersion.*) The instrument consists of a platinum and platinum-rhodium thermocouple which can be plunged into liquid steel so as to give a reading in a few seconds and be withdrawn intact. The main arm of the couple is up to 15 ft. long. The tip is encased in a thin sheath of quartz and the remaining part of the thermocouple is suitably protected by refractory. The thermocouple is connected to a high speed recorder, and it is claimed that accurate measurements can be made after 10 to 15 seconds.

Schoop Process. A method of metal spraying in which metal in the form of wire is pushed into the nozzle of a gas-fired metal-spraying pistol at a constant rate, so that, as the end of the wire is melted and atomized, the position of the wire with respect to the flame remains constant. The gases for melting, atomizing, and spraying, which are led in through tubes, after concentration round the wire, consist of a mixture of hydrogen or acetylene with oxygen or air, according to the melting point of the metal to be sprayed.

Schori Process. A method for coating surfaces in which the powdered material is entrained in coal gas for feeding to the flame, thus minimizing oxidation, whilst a high-velocity air stream surrounding the flame imparts by induction the necessary flight velocity to the heated particles. (S. 22.)

Schroeder's Embrittlement Detector. A device for the detection of boiler water conditions that are conducive to caustic cracking; it consists of a strip of boiler plate bent cold to conform to the recess in which it fits thereby stressing it above its yield point. It is secured into position by a clamping block and the boiler water is led to the extrados of the bend, a minute vapour leakage to atmosphere being established by the use of an adjusting screw, thus simulating evaporative leakage from a seam. Concentration of the water occurs, and if its chemical composition is such as to give rise to caustic cracking the specimen will crack in a typically intercrystalline manner, usually within thirty days. Valves are provided in the pipeline to the device so as to enable the specimens to be replaced while the boiler is under pressure. (S. 25.)

Schuchardt and Shütte Scleroscope. A hardness testing instrument of rebound type, developed in Germany. It has a diamond tipped hammer which falls through a height of 3·5 in. It

appears to give higher readings than the *Shore Scleroscope* with which it has been compared.

Schury Open Hearth Furnace. A regenerative hearth furnace fired with tar or tar-oil for melting steel for foundry purposes. Flame temperatures up to 2000° C. and more are claimed; the oil is vaporized in a combustion head and there mixed with the air entering tangentially. Despite the high flame temperature, the wear on the furnace lining is not excessive; owing to the flat fan shape of the flame, the roof and front wall temperatures are below that of the bath. (B. 115.)

Schwietzke Casting-Round Process. A composite casting process used for the production of the so-called laminated bearing shells, developed to meet the requirements for axle bearings for goods wagons which would stand up to heavier loads and the greater impacts in shunting. The requirement was met by providing in the normal sand mould an assembly of steel laminations, around which the bronze bearing shells are cast. The only preparation given to the steel laminations is sand blasting; no special bonding is aimed at, a purely mechanical keying between the bronze casting and the steel being obtained. (S. 31.)

Schwietzke High-Frequency Process. A casting-on process which operates in a rather similar way to the *Heddernheim Kupferwerke Casting-On Process*. The non-ferrous alloy, which is to form the coating, is melted in a high-frequency electric field, flows round or into the steel backing and is then subjected in contact with the backing to a diffusion heat treatment in the same high-frequency field. (S. 31.)

Schwietzke Immersion Process. A composite casting process in which the steel backing to be coated is immersed in a metal bath containing strong reducing agents, e.g. phosphorus or silicon. After diffusion has set in, the steel coating, now covered with a thin layer of the coating metal, is quickly transferred to a mould in which the coating metal is then cast round the backing. (S. 31.)

Schwingmetall. A process for bonding rubber to steel for the elimination of vibration in machinery mountings. Soft rubber is bonded by a cement between two pieces of metal (usually steel or brass-plated steel), one of which is attached to the foundation and the other to the machinery. (B. 96.)

Sciaky Spot Welder. A resistance welding machine in which the transformer is so arranged that all three phases are drawn upon equally in turn.

Science. The ordered arrangement of ascertained knowledge, including methods by which such knowledge is extended and the criteria by which its truth is tested. The older term, natural philosophy, implied the contemplation of natural processes per se, but modern science includes such study and control of nature as is, or might be, useful to mankind.

Science Library. C/o The *Science Museum*.

Science Museum. South Kensington, London, S.W.7.

Scientific and Industrial Research. (See DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.)

Scientific Societies. (See Appendix V.)

Sciograph. A drawing which shows a sectional view of a building.

Sclerograting. (*Sclerometric.*) A fine grating ruled on a polished metal surface for the purpose of studying relative hardness. (L. 38.)

Sclerometer. An instrument for the determination of hardness by means of a scratch test, which utilizes a standard 136-degree diamond pyramid as a scratching tool. Its loading is accomplished by weights of a high-grade analytical balance. The loaded diamond is lowered on to the specimen and given a translatory motion. The speed of the scratch is regulated by varying the voltage of a small electric motor the gear of which moves the platen with the specimen very much in the same manner as the coarse movement of a microscope. The scratch produced is measured by means of a micrometer eyepiece.

Sclerometric. (See SCLEROGRATING.)

Scleroscope. (See SHORE SCLEROSCOPE.)

Scones. (*Splits.*) Firebricks of a certain standard size.

S.C.O.O.P. Scientific Compilation of Optimum Programmes of the United States Air Force.

-scope. A suffix applied to names of instruments for observing or watching, usually as distinct from measuring, e.g. microscope.

Scorched Ingot. One which has a needle structure and is brittle, probably due to being poured too hot. Such ingots are liable to forge into bars with cracked corners and to *clink* in the reheating furnace.

Scorching. (*a*) Automatically raising and lowering the electrodes in an electric arc furnace in the initial stages of the melting operation until the charge is melted. (*b*) Overheating in grinding.

Scoria. (See SLAG.)

Scoring. The localized erosion or eating away of the surface, often resulting in

the formation of irregular holes and grooves. This effect may be observed for example, in the bores of guns where it is often due to the action of the hot gases from the propellant.

Scoring Hardness. (See MARTENS' HARDNESS.)

Scortecci Process. A process for direct reduction of iron pyrites which depends on the dissociation of pyrites in the absence of air, and in the presence of carbon, with the formation of iron and carbon disulphide. It is claimed that iron yields of more than 95% have been obtained. (S. 32.)

Scottsonizing. A process for surface hardening austenitic stainless steel. The details of the treatment are not revealed. The depth of case is approximately ·003 in. and is hard to a flat file, but the case hardness cannot be measured by any of the standard devices available except the *Knoop tester*.

Scouring. (*a*) Cleaning a metal surface by means of an abrasive and a liquid. (*b*) The combined chemical and mechanical attack on the refractory lining of a furnace by the action of the molten metal and/or slag.

Scouring Cinder. (See SLAG.)

Scragging. A prestressing process used to improve the load-carrying capacity in the manufacture of springs. The spring is loaded in the same direction as it is loaded in service, i.e. it is repeatedly compressed to closure, until a *permanent set* is produced. The residual stresses thus induced oppose the stresses applied during service and after such prestressing followed by a simple heat treatment, the spring will endure nominal stresses well in excess of the elastic limit of the material. (W. 10.)

Scrap. Steel available for remelting.

Scrapalurgy. A term coined by Brearley for the efficient use of *scrap*.

Scrap-Carbon Process. Indian scrap-carbon process using 100% steel scrap in which petroleum coke replaces carbon and acid slag replaces silicon. The hearth is protected from erosion by spreading an easily fusible silica sand over the banks before charging and manganese ore is used instead of iron ore for oxidizing the carbon. The quality of the steel made by this process is claimed to be as high as that obtained by the *pig-and-scrap* process and yields are said to be higher. (Y. 2.)

Scraped Edge. A term applied to the abraded edge of steel sheet or strip, caused by the faulty adjustment of the *guides*.

Scratch Hardness. (See MOHS' SCALE.)

Scratch Hardness Extensometer. An instrument for recording tension-compression strains and also pure shear strain. It is 4 in. long and weighs less than 1 oz. and the record is scratched by a diamond point on a moving steel target. (I. 23.)

Scratch Hardness Tester. The apparatus consists of a microscope in which the diamond pyramid with loading apparatus can be swung into the position of an illuminator. The scratch is made by moving the stage of the microscope to which the specimen is clamped, the loading apparatus swung out and replaced by the illuminator and the dimensions of the scratch measured without moving the specimen. The scratch so produced has sharp edges even on the hardest constituents of an alloy, and its width can be accurately measured. (S. 94.)

Screen. (*a*) A perforated metal screen placed between the *gate* and the *runner* of a casting *mould* for the purpose of separating entrapped oxides or gases during pouring. (*b*) A sieve or *riddle*, used for grading sands, etc.

Screen Analysis. The analysis of particle size distribution in crushed or ground material, expressed in terms of the weight percentage retained upon each of a series of standard screens of descending mesh size and the percentage passed by the screen of finest mesh.

Screening. Separation of crushed or powdered material according to particle size by passing it through sieves of the desired mesh size. (G. 30.)

Screw Axis. (See AXIS OF SYMMETRY.)

Screwdown Gear. (See ROLLING MILL.)

Screw Stock. *Free cutting steel* bars suitable for machining into bolts and screws in an automatic lathe.

Scribed Line Test. A method used in the *tensile test* in which a line is scribed on the test piece with a *pop mark* as a centre, and a radius of 2 in.; the specified proof load is applied, kept on for a period of not less than 10 seconds, and then removed, and a second line scribed with the same radius and the same centre. If two lines are then present on the test piece, indicating that a permanent elongation of more than 0·2% of the gauge length has occurred, the test piece is considered to have failed. This method does not, therefore, provide a direct value for the *proof stress*, but it serves to indicate whether the specified proof load has been successfully withstood.

Scrubbing. (*a*) Purification of a gas by washing in specially constructed towers. (*b*) The operation of passing metal plate, sheet, or strip, after pickling, between revolving brushes, and under a sluice of water.

Scruff. Dross, consisting of a mechanical mixture of tin oxide and iron-tin alloy formed on a tin coating bath. (A. 27.)

Scruff Guard. The apron of metal plate used in a tin-plating mill to prevent *scruff* being carried over on the galvanized steel.

Scruffy Plate. Tinplate, the coating on which is contaminated and roughened with particles of *scruff*.

Scruple. One twenty-fourth of an ounce.

S.C.T. Mould. Abbreviation for a semi-closed top mould.

Scuffing. (*Galling.*) Surface damage which appears to be due to local seizures, the worn surfaces having a rough and torn appearance. It is caused by the high temperature produced by the friction of parts under extreme conditions of speed and load, resulting in the welding, melting and characteristic severe localized failure of the surface.

Scumming. The formation of a scum on the surface of a cyaniding bath. It consists of decomposition products of the bath.

S.D. Soft drawn.

S.D.C. A symbol used in tinplate mills to indicate the thickest gauge sheet.

Se. Chemical symbol for *selenium*.

S.E.A.C. The Bureau of Standards Eastern Automatic Computer. An electronic computer developed in the U.S.A. to work for *S.C.O.O.P.*

Sea Coal. The term was originally applied to coal brought from Newcastle by sea, as distinct from charcoal, etc. It is now applied in American foundries to finely ground coal which is mixed with sands for foundry facings.

Sea Water. The following is a typical analysis of sea water (Gases are not included):

Element	*Parts per Million*	*Element*	*Parts per Million*
Chlorine	18,980	Silicon	0·02–4·0
Sodium	10,561	Fluorine	1·4
Magnesium	1,272	Nitrogen	0·01–0·7
Sulphur	884	Aluminium	0·5
Calcium	400	Rubidium	0·2
Potassium	380	Lithium	0·1
Bromine	65	Phosphorus	0·001–0·10
Carbon	28	Barium	0·05
Strontium	13	Iodine	0·05
Boron	4·6	Arsenic	0·01–0·02

Sea Water Immersion Test. A test designed to measure the protection afforded by coatings against sea water. Coated test panels are placed in synthetic sea water and inspected daily for signs of rusting. Little information is available on the correlation of this test with practice, but it is included in several U.S. Services Specifications. (J. 28.)

Seal Weld. Any weld used primarily to obtain gas tightness.

Sealing. A process used to render anodic coatings on metals non-absorbent. (A. 27.)

Sealing Run. (*Backing Run.*) A light run deposited on the *root* side of a *butt weld*.

Seam. (See SEAMS.)

Seam Weld. A weld consisting of a series of overlapping spot welds, made by *seam welding* or *spot welding*.

Seam Weld Timer. A device which controls the heating and cooling times in *seam welding*.

Seam Welding. A *resistance welding* process in which the electrodes used are in the form of discs. Current is switched on and off regularly as the discs roll over the work, the disc speed and time cycle being adjusted to obtain a series of overlapping spot welds. (W. 61.)

Seaming. The joining of sheet metal by means of interlocking multiple bends.

Seamless Steel Tubes. Methods of producing seamless tubes are characterized by piercing and elongation operations performed by rotary or non-rotary methods, e.g. *Mannesmann*, *Stiefel*, and *cone piercers*, and *Pilger*, *Foren* and *Diescher* mills, which are all rotary. Non-rotary piercing is usually carried out on a hydraulic press, the hollow cylinder produced being elongated by passing through a train of dies. (P. 33.)

Seams. Longitudinal surface defects found in finished or semi-finished products. They appear in the form of shallow grooves or striations and usually originate from sub-cutaneous blowholes which have become elongated on rolling. Seams may also be caused by rippled surfaces or by recurrent teeming laps.

Season Cracking. Cracking resulting from combined corrosion and internal stress. It occurs in severely *cold worked* materials. The term is usually applied to the *stress corrosion* cracking of brass.

Seasoning. (*Weathering.*) A mode of treatment of iron castings which are allowed to remain in storage, or to stand out in the open, for a more or less extended period, e.g. 6 months, in order to effect a reduction in the residual stresses and consequently in the degree of distortion during subsequent machining. A very similar result can often be obtained by a comparatively short period, e.g. 30 mins. of *tumbling*. Since *stress-relieving* by heat treatment is a more certain process, and seasoning involves much delay and the use of considerable space for storage, stress-relieving is more usually employed.

Secant Modulus. (*a*) The secant modulus of elasticity at a designated stress is

the stress divided by the corresponding strain. (*b*) The secant modulus of elasticity at a given amount of strain is the corresponding stress divided by the designated strain.

Secondary Clearance. (See RAKE.)

Secondary Creep. The second portion of the *creep* curve following the initial creep stage and in which the rate of creep has reached a fairly constant value.

Secondary Hardening. Hardening produced by tempering, usually of quenched high-speed tool steels. On tempering these at 400° to 600° C. any *austenite* retained by quenching is converted into the harder *martensite*. Steels containing vanadium, e.g. MoV steel, show secondary hardening at 600° to 650° C. as a result of carbide precipitation.

Secondary Metals. Metals recovered from scrap, as distinguished from *primary* metals, which are obtained direct from the ore. Usually they contain a fairly high proportion of impurities.

Secondary Pipe. (See PIPE.)

Seconds. (See WASTERS.)

Seconite. A finely ground plastic clay which in proportions not lower than 6% gives satisfactory green strength when used as a bond with moulding sand.

Section. (See STRUCTURAL SHAPES.)

Section Mill. A mill designed to roll a variety of sections, e.g. channels, joists, T bars, etc.

Sectional Core. A *core* made in two or more parts and pasted or wired together. (A. 26.)

Sectioning. A term used to cover sampling of welds by trepanning and allied methods. A small sample of a weld is removed for inspection or tests. The opening left by the operation is generally repaired by welding, if necessary. (L. 32.)

Seebeck's Effect. (See THERMO-ELECTRIC EFFECT.)

Seed Blasting. (*Non-Erosive Blasting.*) A process of blasting in which sand is substituted by softer, non-erosive grits such as coffee grounds, seeds, etc. This method does not abrade the surface of the metal and causes no change in dimension so that it can be used on highly finished surfaces and soft non-ferrous metals. Sand blasting equipment can be employed without any change or modification. (M. 102.)

Seed Charge. Material added to a super-saturated solution to act as nuclei and bring about precipitation.

Seeman Bohlin Method. A method of crystal analysis, using a monochromatic or polychromatic X-ray beam of wide angular aperture; an aggregate of small crystals oriented more or less completely at random and spread on a cylinder having an element that passes along the single slit defining the X-ray beam; and a photographic film bent to fit another segment of the same cylinder. This is a focusing method.

Seger Cones. Small cones consisting of mixtures of clay and salt of known melting point. Each individual cone therefore, melts at a known temperature and the cones are manufactured in series to cover a range of temperatures. They are used similarly to *sentinel pyrometers* to indicate the temperature of a furnace.

Seggar. (See SAGGAR.)

Segment Die (*Split Die.*) In powder metallurgy, a *die* made of parts which can be separated for the ready removal of the compact.

Segregation. (*a*) The non-uniform distribution of impurities. The phenomenon depends not only on the chemical composition of the steel but also on the rate of cooling, both of the ingot as a whole, and of each individual point within the mass. For example, and referring more particularly to piped ingots, near the walls, where the rate of cooling is rapid, the segregated impurities are trapped in the rapidly growing crystals. Further inside the ingot, where the cooling is slower, the segregates will collect together and produce the so-called *ghosts*, or they may tend to rise to the surface and collect in the scrapped ingot head. *Thermal conductivity*, *density*, and *specific heat* are also of importance. In major segregation variation occurs over the whole mass and is often revealed by marked lines having a pronounced upright or inverted V-shape which shows up when the ingots are sectioned and etched. Both V and Λ segregations are influenced by the taper of the mould, but both types are less marked if lower casting temperatures are employed. *L segregates* are inclined segregates at the ingot rim. *Micro-segregation* refers to normal segregation on a microscopic scale whereby material richer in alloying element freezes in successive layers round the *dendrites* (*coring*) and in the *constituent network*. *Macrosegregation* refers to gross differences in concentration, e.g. from one area of an *ingot* or *casting* to another. This may be *inverse* or *gravity segregation*. Pipe segregates occur round the *pipe* cavity and *blowhole* segregates are often found lining blowholes in steel ingots. In normal segregation the constituents with the lowest melting points

concentrate in the last portions to solidify, but in inverse segregation this is reversed. (*b*) Sorting mixed scrap into lots of similar composition.

Seizing. (*a*) The partial welding together of sliding metallic surfaces. This is caused by the fact that when two metal surfaces are in contact, minute surface disparities will be deformed beyond their elastic limit, and flow plastically until their area is sufficient to support the applied load. The intense pressure at the points of contact, combined with the plastic flow, will produce welding together of the metals even under static loading. (*b*) Binding a wire rope to prevent unwinding of the strands.

Sejournet Extrusion Process. (*Ugine-Sejournet.*) A hot extrusion process which employs glass in the fibrous or woven form, as a lubricant. To retard wear on the die, oxide is removed from the surface of the billet by carrying out the final heating in a salt bath. It is claimed that the production of most complex forms is now possible. Materials which are hot-short, e.g. 29/9 chromium-nickel stainless steel, high purity molybdenum, heat resistant alloys, titanium metal, and titanium alloys can be successfully extruded by this process. (S. 38a.)

Seku Machine. A portable hardness testing instrument of German manufacture, which carries an indenting tool on a steel spring. The indenter consists of a 5 mm. ball and pressure is applied by means of a vice. A pointer on the scale indicates loads up to 1000 kg.

Selective Block Sequence. In welding, a *block sequence* wherein successive blocks are completed in a certain order selected to create a predetermined stress pattern. (A. 37.)

Selective Carburizing. A method employed when certain portions of the surface of the work are required to remain soft after the case-hardening treatment. Any of the normal methods of *carburizing* may be employed, the only modification being that the specified areas of the work are protected from the carburizing effects, e.g. by copper plating, packing in sand, so that only the desired surfaces are exposed, or by the application of one or other of the various proprietary insulating solutions or pastes manufactured for this purpose.

Selective Freezing. (*Differential or Progressive Freezing.*) The process involved in the solidification of alloys which results in the formation of crystals of a different composition from that of the melt.

Selective Heating. A process by which only certain portions of the steel are heated in such a manner as to develop the desired properties after cooling.

Selective Quenching. A process by which only certain areas of steel are quenched.

Selenide. A compound of *selenium* with another element.

Selenium. (*Se.*) *Atomic weight* 78·96. *Specific gravity* 4·81. *Melting point* 220° C. A metalloid closely resembling sulphur in properties, and which, likewise, can exist in three different forms. Only one of these is distinctly metallic, and possesses a steel-grey lustrous appearance, occurring in hexagonal crystals. Selenium boils at 690° C. and gives off dark yellow fumes which condense as "flowers of selenium". It burns readily in air when heated and dissolves readily in acids. It combines with other elements to form selenides, similar to sulphides. It is very sensitive to small variations in light intensity, which instantaneously vary its electrical conductivity, this property being used in the construction of photo-sensitive devices. Its main uses are in the electrical and electronic industries, for example, in rectifiers to convert alternating to direct current, and the radio and television industry. The element occurs with sulphide ores and is obtained as a by-product in the electrolytic refining of copper. The U.S.A. is the biggest producer of selenium, all from this process, but most of Great Britain's supplies come from Canada. Selenium coatings are claimed to confer protection against corrosion, and it may be added in amounts of up to about 0·60% to stainless steels to provide free-machining qualities.

Selenium Copper. Copper to which about 0·5% selenium has been added with the object of improving the machining properties.

Selenium Process. A means of producing a coating of *selenium* on magnesium alloys for the purpose of conferring protection against sea-water corrosion. The treatment consists of immersion, (i) in a 10% solution of selenious acid containing 1% sodium chloride or (ii) in a solution containing sodium selenide and phosphoric acid.

Selenium Steel. (See SELENIUM.)

Self Annealing. A term applied to metals such as lead, tin, and zinc, which recrystallize at air temperature and in which little *strain-hardening* is produced by *cold-working*.

Self Baking Electrode. (See SODERBERG ELECTRODE.)

Self Diffusion. The movement of atoms through a *lattice* in which all atoms are

identical, migration occurring simply by exchange of position.

Self Fluxing Ores. Iron ores that contain, as mined, sufficient lime to combine with their silica or gangue contents and form a slag.

Self Hardening Steel. (See AIR HARDENING STEEL.)

Self Indicating Type Machine. A machine in which the applied load is automatically indicated on a dial, or other indicating mechanism.

Self Inductance. (See INDUCTANCE, SELF.)

Self Printing X-Ray Diffraction Interplanar Scale. (See X-RAY DIFFRACTION INTERPLANAR SCALE.)

Self Propagating Reaction. A reaction which when started can proceed without further application of extraneous energy since it produces sufficient heat to keep the temperature of the products of reaction above that necessary to initiate the reaction. (S. 3.)

Self Re-Ignition. In *welding*, the sudden breakdown of the gap from the *restriking voltage* to an arcing condition, without auxiliary means for initiating the break-down. At a sufficiently high open-circuit voltage, self-breakdown occurs regularly and the arc becomes self running.

Self Reversal. In *spectrographic analysis*, the result of absorption, by the cooler outer vapour of the light source envelope, of radiation emitted by the hot central core of the light source. The degree of self reversal is variable and, in extreme cases, is recorded on a photographic plate as a broadened diffuse black image with a fine central transparent line.

Self-Stifling Reaction. A corrosion attack in which the corrosion product tends to form a surface layer protective against further attack.

Semi Centrifugal Casting. (See CENTRIFUGAL CASTING.)

Semi Centrispinning. (See CENTRISPINNING.)

Semi-Continuous Mill. (See ROLLING MILLS.)

Semi-Duplex Process. The process consists essentially of pouring molten metal from a primary *open hearth furnace* on a heated solid charge of heavy and light alloy scrap (20% to 40% of total). The charge is melted and finished under reducing conditions. There is no *boil*.

Semi-Finished. (See FINISHED STEEL.)

Semi-Hardening. A hardening treatment for martensitic steels in which the steel is quenched from such a low austenitizing temperature that only a portion of the metal transforms, thus a semi-martensitic alloy which is particularly suitable for machining.

Semi-Killed Steel. (See BALANCED STEEL.)

Semi-Metal. A term, now obsolete, for non-malleable metals as for example, *bismuth* and *arsenic*.

Semi-Permanent Mould. A permanent mould in which sand cores are used. (A. 27.)

Semi-Siliceous Bricks. Bricks containing 78% to 85% *silica*.

Semi-Steel. The name sometimes given to the metal resulting from the addition of mild steel to the charge of pig iron in the cupola. The term is a misnomer, for the product is still cast iron although the total carbon content is lower than usual and the graphite is in a finer state of division.

Semi-Water Gas. A mixture of carbon monoxide, carbon dioxide, hydrogen and nitrogen obtained by passing a mixture of air and steam continuously through incandescent coke. Its *calorific value* is low, about 125 B.Th.U. per cu. ft.

Sendzimir Galvanizing Process. In this process the surface of the base metal is first oxidized and the oxide then reduced. The oxidation may be achieved by heating in an oxidizing medium or by other chemical means, and the reduction is carried out in a furnace having a suitable atmosphere. (O. 16.)

Sendzimir Mill. A cold strip rolling mill, developed on the lines of the *cluster mill* which employs small and relatively slender work rolls. Each of these is backed by two larger rolls. These in turn are backed by three still larger rolls. In another type, four further support rolls are used beyond these three. (See Plate XIV and Fig. 9.) (See also ROLLING MILLS.) (S. 40.)

Sengierite. ($2CuO.2UO_3.V_2O_5.10H_2O$.) A vanadium ore.

Sensation Unit. The former name of the *decibel*.

Sensible Heat. The heat absorbed or emitted by a body or gas on heating or cooling through a certain range of temperature, no change of state or of allotropic form being involved.

Sensitization. A phenomenon characteristic of the austenitic corrosion-resisting steels which causes some subtle change in the grain boundaries when heated in the temperature range of 450° to 800° C., destroying the corrosion resistance of such areas to such an extent that granulation of the steel may occur during subsequent service. (See INTERCRYSTALLINE CORROSION.)

Sentinel Pyrometers. Cones 1 in. long, ⅜ in. diam. composed of salts or metal

(*Reproduced by courtesy of Shepcote Lane Rolling Mills Ltd*)

Plate XIV.—Inserting roll in Sendzimir cold rolling mill.

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amalgams of known melting points, the cones being prepared in series to cover a range of temperatures. A sentinel of the desired melting point is selected which, on exposure to heat, indicates the attainment of that temperature by collapsing.

Separator. A mechanical unit which separates or grades ground materials into constituent parts, used in the foundry to remove *fines* from the sand and dust from the air.

Sepia Negative. A brown-background negative made on iron-silver sensitized paper, used as an intermediate in making *shop prints* from drawings, sometimes called brown print. Positive prints made on such paper are usually called *brown line prints*.

Sequence Timer. In *resistance welding*, a device for controlling the sequence and duration of any or all of the elements of a complete welding cycle, except weld time or heat time. (A. 37.)

Sequence Weld Timer. In *resistance welding*, a device for controlling the sequence and duration of any or all of the elements of a complete welding cycle. (A. 37.)

Series. In X-ray spectra, a group of characteristic X-rays having the same excitation limit; distinguished as K series and L series.

Series Welding. A *resistance welding* process wherein two or more welds are made simultaneously by a single welding transformer with the total current flowing through every weld.

S.E.R.A.P. Société D'Études, de Recherches et D'Applications des Poudres Agglomérés.

Serumite. A bonding clay for foundry sands.

Servarizing. The process consists of treatment partly in an aqueous solution and partly in a molten electrolyte producing on the parts so treated an envelope of alumina, which alloys with the base metal, forming a highly refractory and non-scaling coating. The object of the treatment which is applied either to iron or steel is to afford protection at high temperatures. (M. 97.)

Servo Mechanism. Apparatus for exercising accurate and more or less remote control. (W. 42.)

S.E.S.A. Society for Experimental Stress Analysis (U.S.A.).

Sesci Furnace. A furnace used for the production of high-grade cast iron. It is cylindrical in shape, resting on two pairs of short roller paths; it is rotated by a chain drive. Pulverized fuel is used, and the furnace is charged by means of a water-cooled apron conveyor. (F. 31.)

Sesqui. A prefix denoting the presence of two kinds of atoms in the proportions of 2:3, e.g. manganese sesquioxide Mn_2O_3.

Set. A tool used in the final stages of producing a hole in a *wire drawer's plate* after it has been punched out to a slightly less diameter. The size and shape of the set corresponds to that of the wire to be drawn.

Set Down. A change in diam. in the production of a forging.

Set Gate. A *gate pattern*, used to form a *gate* or *sprue*, set against the pattern. (P. 1.)

Set Off Box. A box or frame without bottom or top, on which a *cope* is placed when lifted from the *drag*.

Setter. (See BENDER.)

Setting Down. Reducing the cross-sectional area of any particular part of a forged piece.

Settling. Separation of a denser solid from a liquid by gravity.

Sevilla Ores. Spanish brown and red *haematite*, with a very low phosphorus content and containing about 60% iron.

S.f.p.m. Surface feet per minute.

S.F.S.A. Steel Founder's Society of America.

S.G. *Specific gravity*.

S.G. Iron. Abbreviation for *Spheroidal Graphite Cast Iron*.

Shackle. (*a*) A metal loop or link for fastening or coupling. (*b*) The device for holding the test piece in a tensile testing machine.

Shake Out. The operation of removing *castings* from the *mould*. (A. 26.)

Shaking Down. An American term for *rabbling*.

Shallow Hardening Steel. A steel having a low hardenability. When quenched in a suitable medium, martensitic hardening is confined to the surface layers only.

Shank. (*a*) The handle attached to a small ladle. (*b*) A hand ladle for carrying and pouring molten iron. (*c*) The straight part of a tool between the head and the handle, e.g. the portion of the tool by which it is held in position in forging or, in a twist drill, that portion of the drill by which it is held and driven.

Shape. Rolled or drawn metal having a cross-section other than round, square, rectangular, hexagonal or oval. (See STRUCTURAL SHAPES.)

Shape Strength Tests. Tests in which the fatigue strength is first determined by alternating stress tests after which the stress distribution is found by stress measurements on models or finished parts. These tests have been developed to prove the theory that fatigue strength

is dependent not only on the strength of the material and cross-section, but also on the shape of the structure. (B. 43.)

Shape Weight. The weight of material contained in the geometric volume to the specified dimensions.

Shaped Wire. Wire having a cross-section other than round.

Sharp Sand. A sand that is substantially free of bond. The term has no reference to the shape of the grains.

Shatter Cracks. (See FLAKES.)

Shaving. (*a*) Trimming heavy gauge blanks to remove uneven sheared edges. (*b*) Forcing a forging through a die to attain a specified dimension with greater accuracy.

Shaving Die. A sizing tool in which a die casting is reduced to drawing dimensions by shaving off the draft on the sides, as distinct from a *trimming die*, in which the flash is sheared flush with the wall of the casting. (B. 20.)

Shaw Process. (See OSBORN-SHAW PROCESS.)

Shear. (*a*) A type of cutting operation in which the metal object (sheet, wire, rod or such) is cut by means of a moving blade and fixed edge or by a pair of moving blades that may be either flat or curved. (*b*) A type of deformation in which parallel planes in metal crystals slide so as to retain their parallel relation to one another, resulting in block movement. (A. 27.)

Shear Bow. A bend in one end of a plate or sheet caused by cutting with a guillotine shear.

Shear Crack. A diagonal, transgranular crack caused by shear stresses.

Shear Distortion. A deformed end on a bar, caused by defective or improperly adjusted shearing equipment.

Shear Drag. In the hot cutting of slab the distortion which appears at the end of a cut slab, caused by incorrectly set and/or worn blades in the shears. (R. 21.)

Shear Modulus. (See ELASTIC MODULUS.)

Shear Steel. An old type of cutlery steel made by hammering together a number of *cemented* bars. (See CEMENTATION.)

Shear Strength. The ability to withstand *shearing stress*.

Sheared and Opened. The stage in *rolling* where the hot rolled pack is squared by shearing and separated into individual sheets. Sometimes referred to as *S and O*.

Sheared Edge. The more or less jagged edge of a plate or sheet caused by *shearing*. (See EDGE CONDITION.)

Sheared Plate. Plate rolled in a *sheared plate mill* and which, therefore, has to be sheared on all four sides.

Sheared Plate Mill. A mill for the rolling of plates which, because straight horizontal rolls only are used, and no edging rolls, must be sheared on all four edges.

Shearing. (*a*) The term used when cutting is effected by subjecting the piece to *shearing stress* at the point where the cut is required. (*b*) Converting into shear steel. (See CEMENTATION.)

Shearing Stress. The stress which tends to cause adjacent parts of the material to slide over each other.

Shearing Test. A test applied to thin material to determine the stress required to cut it across its section.

Shears. (*Guillotine.*) A machine consisting essentially of two blades arranged parallel to one another, with their faces in approximately the same vertical plane and normal to the horizontal axis of the piece to be cut. The distance between the edges of the blades in their extreme open position is sufficient to allow the maximum section rolled to pass through freely. Means are provided for moving either or both blades relative to one another so that in the closed position they overlap slightly, thus ensuring complete severance of the piece. Shears differ in three fundamental respects, i.e. direction of cutting, method of developing cutting power, and construction of the frame; the variants of these may be combined in any way desired. (K. 21.)

Sheath Rolling. A method of consolidating metal powder, e.g. titanium, which consists in sealing it in welded metal containers and working the assembly at elevated temperatures. It is claimed that metal prepared in this manner is dense and sound. (L. 44.)

Sheathed Electrode. A metal electrode provided with flux between the metal core and a metal sheath.

Shed-Exposure Test. A corrosion test in which the coated panels are hung in a shed or louvred cabinet so that they are subject to atmospheric conditions of temperature and humidity without being exposed to direct rain or sun. Sometimes a pan of water or salt solution is placed in the exposure cabinet to keep the atmosphere humid. (J. 28.)

Sheet. A flat piece of steel or other metal obtained by rolling and usually not over $\frac{1}{8}$ in. in thickness; although in some classifications, including the $\frac{3}{16}$ in. thickness.

Sheet Bar. A semi-finished hot rolled iron or steel product of rectangular section intended for the production of sheet by cross rolling.

Sheet Bar Multiple. A length of steel from which a number of *sheet bars* can be cut with a minimum residue.

Sheet Furnace. A furnace for reheating steel sheet between rolling operations.

Sheet Separation. In spot, seam and projection welding, the gap surrounding the weld, between *faying surfaces*, after the joint has been welded. (A. 37.)

Sheet Slab. Slab intended for the production of sheet.

Sheet Nickel. Electrolytic nickel.

•**Sheffield Composition.** Usually known as *compo*.

Sheffield Nickel Silver. (See NICKEL SILVERS.)

Sheffield Process. A *basic open hearth* process using charges so low in sulphur and phosphorus that they could be used in the *acid process*; the pig iron charged is haematite iron. The charge contains all the elements required to give the required analysis, plus the usual margin of carbon. The charge contains about 0·5% of silicon and a maximum amount of manganese, in order to ensure correct conditions in the bath. Nickel-chromium-molybdenum steels can be made by this process, and high yields of the valuable alloying elements are obtainable from scrap charges. No melting and slag difficulties are experienced if the chromium bearing materials are charged first and covered with carbon steel turnings, the limestone and iron being added last of all. (B. 126.)

Sheffield Plate. A compound plate having a copper base with a layer of silver rolled on it. The craft of making plate in this manner has now become obsolete and articles of Sheffield plate are highly valued.

Sheffite. A proprietary descaling fluid.

Shell. (*a*) An article formed by *deep drawing*. (*b*) The metal sleeve remaining when a billet is extruded with a dummy block of somewhat smaller diameter. (*c*) (See SCAB). (*d*) (See SPLASH). (*e*) (See also SHELL MOULDING).

Shell Lime. Lump lime which when flaked has a characteristic shell-like appearance. It is used mainly in Scotland.

Shell Moulding. (*Cronizing*.) The process consists essentially of depositing evenly over the face of a heated metal half-mould pattern plate, a finely divided mixture composed principally of sand and a thermosetting phenolic resin. This is usually referred to as *investing* the plate with the sand-resin mixture. The heat from the plate causes the resin to melt and form a thin *shell*, about ¼ in. in thickness, over the entire surface of the pattern. After curing at a temperature of between 350° and 450° C. for a short period, the shell half-mould, or biscuit, is removed from the plate and either assembled at once for pouring the casting or stored until required. The two halves of the complete mould are held together by clips or other convenient methods and the pouring of the metal can be conducted in either the horizontal or the vertical plane, the method of holding the mould being adapted to suit the circumstances, although the horizontal position is generally preferred. Soon after pouring, the hot metal ignites the resin binder, which is rapidly burnt out and the casting may be freed from the remaining sand by subsequent tapping or shaking. The process is applicable to virtually all ferrous and non-ferrous metals, although special precautions are necessary when casting magnesium as this metal reacts chemically with the resin binder. The inner faces of the shell mould are smooth and the resultant castings have a highly satisfactory and even surface. It is claimed that limits can be held to + 0·002 in. or 0·003 in. over each half of the casting. (See also D SHELL MOULDING; OSBORN-SHAW; and POLYGRAM CASTING.) (E. 61.)

Shellac. An animal *resin*, produced by insects parasitic on certain trees in India and Southern Asia. It is used in lacquers and varnishes and as a modifier for synthetic resins.

Shelliness. (*Spelliness*.) Defects appearing on the surface of the ingot due to the splashing of the liquid steel on to the wall of the ingot mould during teeming. The globules of steel thus formed become oxidized and are not taken into solution by the rising metal surface. They are then loosely attached to the surfaces of the resulting ingots and on rolling are flattened out into thin tongues of metal. (G. 51.)

Shelling of Rail. A defect evidenced by plastic flow of the head metal especially at the gauge corners where bearing pressures are highest. After considerable flow in one direction and another has taken place, the metal begins to separate from the parent body in thin leaves or slivers. Pieces break out, leaving sharp re-entrant angles which lead to transverse fatigue cracks, or possibly longitudinal split heads. (L. 15.)

Shepherd Disc Hardenability Test. The hardenability of shallow hardening steels is determined by brine quenching slabs of various thicknesses in a special spray. These slabs are sectioned after hardening with a thin grinding wheel and etched to show depth of hardening. The hardenability is reported as the

number of 32nds of an inch thickness of the thinnest slab which shows a core width of $\frac{1}{16}$ in. or larger. (S. 55.)

Shepherd P.F. Test. (See PENETRATION FRACTURE TEST.)

Shepherd Standards. A series of ten hardened steel fractures ranging from No. 1, which is relatively coarse to No. 10, which is comparatively fine. (See FRACTURE TEST.)

Sherardizing. A method of applying a protective zinc coating to steel in which the components to be treated are packed in boxes which are filled with sand mixed with a controlled amount of zinc. The boxes are heated in gas-fired furnaces to a temperature below the melting point of zinc, both time and temperature being carefully controlled. About $\frac{1}{2}$ oz. of zinc is taken up per square foot of surface with a dimensional increase of about 0·0006 in. (I. 6.)

Sherrite Process. A continuous electrolytic method of coating steel sheets with zinc. The sheets, forming the cathode, are propelled by rollers through the plating baths. The product is named "Sherrite" sheet. The coated surface is uniform, matte and grey, and rusting does not occur even at a cut raw edge; a further advantage of the process is that close-annealed sheets can be used instead of bright or hard-rolled steel plate. The process has been extended to the coating of steel sheet with brass and copper. (E. 38.)

Sherwin Electromagnetic Vibrator. A device for handling moulding boxes and castings at the knock-out station. The moulding boxes are transferred from the mould conveyor by a pneumatic pusher to the vibrating shake-out. The sand and castings fall from the boxes on to the grid of the trough mounted on the vibrator, the sand falling through the grid on to the sand return belt and the castings travelling forward along the grid to the conveyor, which discharges them into skips attached to the cooling conveyor. The moulding boxes, which are positioned on the trough by means of guide strips, travel to the conveyor for return to the moulding machines. The guide strips fitted to the boxes also serve as a protection against wear of the bottom face. (I. 81.)

Shielded Carbon Arc Welding. An *arc welding* process wherein coalescence is produced by heating with an electric arc between a carbon electrode and the work. Shielding is obtained from the combustion of a solid material fed into the arc and/or from a blanket of flux on the work. The application of pressure and/or the use of a filler metal are optional. (A. 37.)

Shielded Inert Gas Metal Arc Welding. (*Sigma Welding.*) (See INERT GAS ARC WELDING.)

Shielded Metal Arc Welding. A process in which fusion is produced by heating with an electric arc between a covered electrode and the work. Shielding is obtained by the decomposition of the electrode covering. No pressure is applied and the filler metal is obtained from the electrode. (A. 37.)

Shielded Stud Welding. An *arc welding* process wherein coalescence is produced by heating with an electric arc drawn between metal-stud, or similar part, and the other work part, until the surfaces to be joined are properly heated, when they are brought together under pressure. Shielding is obtained from an inert gas such as helium or argon. (A. 37.)

Shift. (*a*) (*Cross Joint*). A casting defect caused by the *mismatch* of *cope* and *drag*. (A. 26.) (*b*) (See FLASH).

Shim. (*a*) A piece of steel of suitable quality and shape, used in the *Thermit Combined Weld Process*. (*b*) In engineering, a thin sheet of metal applied between parts as packing.

Shimer Case Hardening Process. In this process the base of the bath is a mixture of sodium and calcium chlorides. This bath is given case-hardened properties by adding small lumps of calcium cyanamide. (S. 54.)

Shingler. (*Knobbler.*) The man who carries out the operation of *shingling*.

Shingling. (*Nobbing, Nobbling, Knobbling.*) A stage in the *puddling process*, in which the ball of iron is hammered or squeezed to form a *bloom* or *billet* of roughly rectangular slab, with the object of solidifying the metal and expelling, as far as possible, the intermixed liquid slag.

Ship Plate. Plates of mild steel made of semi-killed steel to Lloyd's specification 26/32 tons tensile. An increasing demand for exceptionally wide plates has arisen because of the application of welded construction in the shipyards. Plate widths up to 120 in. are required. (B. 17.)

Shirt. An American term for the lining of a *blast furnace*.

Shock Compacting Metal Powder. A development of the known method of compacting powders in a rubber bag by means of hydraulic pressure. The novelty consists in exerting the pressure through a piston actuated by the explosion of a calculated amount of smokeless powder, the pressure being, for instance, of the order of 22 tons/sq. in. (K. 17.)

Shock Testing. (See IMPACT TEST.)

Shoddy. An iron slag mixture which refuses to separate at the skimmer on tapping the blast furnace. It appears as an oily layer on the surface of the iron leaving the skimmer.

Shoe. (*a*) A holder used as a support for the stationary part of *trimming* or *forging dies*. (*b*) In a rolling mill, a girder lying parallel to the rolls and bolted to the foundation, to which the roll housing is clamped.

Shop Print. The working print used by the craftsman; it is generally a reproduction of an architectural or engineering drawing on *blueprint* or *direct-process paper*.

Shore Monotron. The object of this test is to produce the same impression in all materials. The load required to produce this impression is then a measure of the hardness of the specimen. The elastic deformation of the instrument during the test will affect the results unless it is compensated in some way and the designers of the instrument state that this object has been achieved. The instrument has two dials, one which registers the depth of the impression, whereby an impression of pre-determined depth may be obtained and the second which registers the load to produce this deformation. The instrument differs from the Brinell machine in that the deformation produced by the indenter includes the elastic as well as the plastic deformation. (W. 68.)

Shore Scleroscope. An instrument which consists essentially of a small diamond-tipped hammer which falls freely down a graduated glass tube from a constant height on to the surface of the sample under test. The *hardness*, or the elastic quality, is measured by the height of the rebound. In one form of the instrument the rebounding hammer actuates the pointer of a scale so that the height of the rebound is recorded.

Short. The remainder from a coil of strip from which specified lengths have been cut. (See also COLD SHORT, HOT SHORT and RED SHORT.)

Short Hole. An American term for a *tap hole* which has not been adequately stopped.

Short Run Castings. A term applied (*a*) when there is insufficient metal in the ladle to fill the *mould*; (*b*) when the metal freezes in the *gates*, owing to their being too small, and thus prevents the mould from filling up. (P. 9.)

Short-Time Tensile Tests. Elevated temperature tensile tests carried out in conventional tensile testing machines in which the test piece is surrounded by a portable furnace, the temperature of which can be accurately controlled. The testing procedure is similar to that used for ordinary tensile testing, in general an extensometer being used. It is usual to record the limit of proportionality, various proof stresses (0·05%, 0·1%, etc.), ultimate stress, elongation %, and reduction of area %. Owing to the possibility of creep occurring at elevated temperatures, the speed of pulling may be important and it is customary to record it, since results can only be compared when the same rate of pulling is used.

Short Ton. (*Net Ton.*) 2000 lb.

Shorter Process. (See FLAME HARDENING.)

Shorterizing. (See FLAME HARDENING.)

Shortness. *Brittleness* in metal.

Shorts. In the screening of crushed ores, the product remaining on the screen or sieve (as opposed to *fines*, which pass through).

Shot. (*a*) Any missile discharged from a firing piece. (*b*) Small round lead pellets. (*c*) Globules of metal formed in the body of a *casting* and harder than the remainder of it. (*d*) (See SHOTTING).

Shot Blasting. A method of cleaning the surface of metals by abrasion, as in *sand blasting*, the sand being replaced by broken shot or steel grit. It is less effective than sand blasting, as the peening effect of the shot tends to drive the unwanted deposit, e.g. oxides, into the surface of the metal.

Shot Peening. A process in which showers of steel or iron shot are thrown at high velocity, by means of air blast, against the surface of a metal with the object of strengthening the material against failure by fatigue. It should be distinguished from *shot blasting*, which is used for cleaning purposes only. Shot peening is a *cold working* process in which the series of small, overlapping indentations prestress a thin surface layer in compression.

Shotting. (*a*) A process in which molten metal is dropped from a height to form rounded metal pellets or *shot*. The droplets freeze into spherical particles before reaching the water tank at the bottom of the fall. (*b*) In the *Byers* process for the production of wrought iron, pouring refined iron into a ladle containing molten slag.

Shotweld. A process in which the equipment developed to produce the shotweld connections, proportions the diameter of the spot weld to the thickness of the stock and produces welds of uniform strength by accurately controlling the welding current, time and electrode pressure. In addition, it provides a positive check on the

correctness of each welding operation by registering any variance in either time or current on a recording tape. (N. 22.)

Shoulder Effect. The term as used in the production of steel castings refers to the difficulty in forcing steel around corners during solidification.

Shower Gate. In a *mould*, a gating system by which metal showers into the mould cavity from a group of small gates at the top.

Shrink. (See SHRINKAGE CAVITIES.)

Shrink Away. An American term for a defect in hot forging caused by recession of metal from an internal cavity.

Shrink Head. (See FEEDER HEAD.)

Shrink Hole. An obsolete term for the *pipe* in a steel ingot.

Shrinkage. (*a*) The contraction of metal when cooled from an elevated temperature. This includes *liquid shrinkage*, i.e. the contraction in volume as the molten metal cools from a higher temperature to that of solidification; *solidification shrinkage*, i.e. the contraction in volume when the metal (or alloy) passes from the liquid to the solid state at the freezing point, which may extend over a range, and *solid shrinkage*, which is the contraction on cooling from the freezing point to normal temperatures. (*b*) In *powder metallurgy*, the decrease in the dimensions of a compact which may occur during *sintering*. (*c*) The decrease in dimension in clays which occurs on drying at 100° C. and to an even further extent on firing.

Shrinkage Cavities. (*a*) (*Cavitation*). Defects in castings varying from cavities to looseness of structure. They are the result of *solidification shrinkage* and progressive freezing of the metal towards the centre. (*b*) (See PIPE).

Shrinkage Cracks. Cracks formed in metal as a result of the pulling apart of grains by thermal contraction before complete solidification. (A. 26.)

Shrinkage Rule. (*Moulder's Rule.*) A ruler used in making patterns for castings, on which the graduations are expanded to account for thermal and solidification contraction of the metal being cast. (A. 27.)

Shrinkage Stress. That stress induced by contraction due to cooling. (See RESIDUAL STRESS.)

Shunt. A resistor of low value used for the measurement of electric current by means of a potentiometer, or of an ammeter, through which only a fraction of the total current passes.

Shut. (*Lap, Overlap.*) A defect found on wrought steel caused by the folding back of the surface against itself.

S.I. Abbreviation for *Statutory Instruments*.

Si. Chemical symbol for *silicon*.

Side Arch Pups. Firebricks of a certain standard size.

Side Blown Converter. (See BESSEMER PROCESS.)

Side Centred. Concerning orthorhombic space lattices. Having equivalent points at the corners of the unit cell, and at the centre of the pairs of opposite faces perpendicular to the a-axis or to the b-axis; the same as, *end centred*, but with a different choice of crystallographic axes. (A. 27.)

Side Cramp. Excessive pressure on one side of the *die* in die forging.

Side Shearing. (*Edging.*) Trimming the edges of cold rolled *strip* to obtain uniform width.

Side Spectrum. A row of spots indicating planes equally inclined to the axis of rotation or oscillation, but not parallel thereto. (See also LAYER LINE and ZERO SPECTRUM.)

Side Top Rake. (See RAKE.)

Siderite. (See SPATHIC IRON ORE.)

Sideroferrite. Metallic iron found in fossilized wood.

Siebel and Pomp Test. (*Draw-Widening Test.*) In this test, a circular blank with central hole is gripped round the edge and pressed by means of a flat-headed punch. The metal round the central hole is thus drawn radially outwards over the profile radius of the punch until its capacity for stretching is exhausted, whereupon fracture occurs by cracks at the rim of the hole. (S. 64.)

Siemens, Sir Charles William. (1823–83.) A German by birth, but English by adoption, his progressive researches led to the development of the regenerative gas furnace which, in 1861, had attained such success that he proposed its application to the manufacture of steel in the *open hearth*. He erected his experimental open hearth plant in Birmingham in 1865, but it was not until 1867 that the initial difficulties were overcome and his efforts were crowned with success. In 1873 the total quantity of open hearth steel produced in the United Kingdom was 77,500 tons, but by 1882, 354 open hearth furnaces had been erected throughout the world, equal to an annual production of 1,442,000 tons of steel.

Siemens Gas. (See PRODUCER GAS.)

Siemens-Martins Process. The name given on the Continent to the *Open-Hearth Process*.

Siemens Open Hearth Furnace. A furnace, of *reverberatory* type, used in

steel making. (See OPEN HEARTH FURNACE.)

Siemensite. A highly refractory material, produced by the fusion of chromite, bauxite, and magnesite, in the open electric arc furnace. (S. 74.)

Sieurin Process. A method for the direct production of iron and steel from ore, first used on a large scale at the Höganäs Company's works in Sweden, in 1911. The reduction is carried out with charcoal and the extra heat necessary is obtained by burning producer gas. The ore and powdered coal, lying in alternate layers, are heated in a closed round-brick chamber operated on the same system as the gas-fired ring furnace used in potteries. The air is preheated and the gases of combustion are made to preheat the material which is to be burnt.

Sieve Sizes. Sieves are standardized in British Standard 410, and sieve size diamond powders in British Standard 1987.

Sigal. An aluminium-silicon alloy of approximately eutectic composition; it forms a satisfactory pigment in an anti-corrosive paint for use on steel and other structures. Special grades have been developed for use at high temperatures and to resist certain specially corrosive atmospheres. (M. 118.)

Sigma Hardness Tester. A *micro-hardness* tester, which indicates the depth of indentation under increasing load. The diamond indenter (preferably the double cone indenter) is suspended in parallel spring strips. The deflection under load is measured by an air jet blowing against a polished sapphire plate. The load is applied by a weight through a counter-balanced beam suspended in miniature ball-bearings, while the weight is moved by a thread wound up by a synchronous motor. Another synchronous motor operates the strip chart which plots the depth of penetration over the load applied. From this, a log-log diagram may be derived which would enable one to obtain automatically the *Meyer analysis*. (M. 115a.)

Sigma Microtest. The instrument indicates on a scale in micro-inches the centre line average value of submitted surface finishes. The head contains a piezo-electric crystal with a diamond cone stylus radiused to 0·0005 in., while the underside of the head is shod with three skids to provide a reference plane. (M. 84b.)

Sigma Phase. (σ.) A hard brittle non-magnetic compound. It was at first identified as the simple compound, FeCr, but it has been found that the composition of the phase may be extended to include other elements, notably nickel, molybdenum, silicon, vanadium, manganese and aluminium, without affecting its crystallographic form, i.e. it appears that atoms of either of the components may be replaced to some extent by atoms of a number of other elements. The phase is stable below 930° C. but at higher temperatures transforms to magnetic alpha (ferrite). The transformation is a sluggish one. Sigma may be the cause of serious embrittlement particularly after long exposures in a certain range of temperature. (K. 27.)

Sigma Signal Indicator. An electric visual gauge comprising a unit or measuring head carrying three signal lights, a measuring spindle and two micrometer adjusting screws, designed primarily to facilitate the rapid inspection of components where it is only necessary to establish either plus or minus rejects and not necessary to measure the amount of error. (M. 30.)

Sigma Welding. The sigma (*shielded inert gas metal arc*) process uses a consumable electrode as contrasted to the virtually non-consumable tungsten electrode of the inert gas shielded tungsten-arc or heliarc process.

Silcaz Alloy. A proprietary boron addition agent for increasing the hardenability of steel.

Silex. Ferro-silicon mixed and bonded with chemical agents to furnish extra heat by means of exothermic reaction when the material is added to the bath.

Silica. (SiO_2.) (*Silicon Dioxide.*) Silica forms 60% of the earth's crust and is the chief constituent of sand and silicate clays. It is extremely *refractory*, melting point 1750° C. In the form of *ganister* it is used for lining *acid open hearth* and other furnaces where resistance to high temperatures and the attack of acid slags is required.

Silica Bricks. Bricks containing at least 92% *silica*. (F.38.)

Silica Flour. Material commonly produced by pulverizing pure grains of quartz sand in large ball mills. It contains 99·5% pure silica, and is used in foundry practice for improving the finish and increasing hot strength of moulds. It is also used in the production of core and mould washes.

Silica Gel. A colloidal form of silica prepared by treating sodium silicate with acetic acid or hydrochloric acid, washing and drying. It is highly absorbent and its various applications include that of a drying agent both in the laboratory and industry.

Silica Sand. Sand with a minimum silica content of 95%. It is used for the formation of *moulds* for *castings*.

Silicate. Silica combined with a metallic oxide, e.g. ferrous silicate $FeSiO_3$.

Siliceous. Containing *silica* or *silicates*.

Siliceous Bricks. Bricks containing 85% to 92% *silica*. (Cf. SILICA BRICKS.)

Siliceous Ores. Iron ores in which the gangue consists mainly of silica.

Silicic Acid. Meta-silicic acid, H_2SiO_3; ortho-silicic acid, H_4SiO_4.

Silicide. A binary compound of silicon with a metal.

Silicoferrite. (See FERROFERRITE.)

Silico-Manganese. An alloy employed for adding manganese to steel and also as a deoxidizer and scavenger of steel. It usually contains 65% to 70% of manganese and 12% to 25% of silicon. It is graded according to the amount of carbon, generally, 1, 2 and 2·5%. For making steels low in carbon and high in manganese, silico-manganese is more suitable than *ferro-manganese*.

Silico-Spiegel. An alloy of silicon and manganese with iron, employed for making furnace additions of silicon and manganese to *open hearth* steels. A typical analysis gives 25% to 30% manganese, 7% to 8% silicon, and 2% to 3% carbon. Both the silicon and manganese act as strong deoxidizing agents, forming a thin fusible *slag*.

Silicon. (*Si.*) *Atomic weight* 28·09. *Specific gravity*, amorphous 2·33, crystalline 2·42. *Melting point* 1420° C. A non-metal, resembling carbon in chemical properties and existing in three forms, amorphous, graphitoidal, and crystalline. Silicon is the most widely distributed element in the earth's crust; it never occurs free in nature but as a compound, usually *silica* (SiO_2), e.g. sand, or a silicate, e.g. clay ($2H_2O.Al_2O_3.2SiO_2$). Silicon is a powerful deoxidizer, and effectively eliminates oxides from the molten bath in all steel-making processes, for which purpose it is added in the form of *ferro-silicon* in amounts up to about 0·80%. When used as an alloying element, silicon in small percentages will increase the tensile strength, and yield point of structural steels. It is used in amounts of 1·5% to 2% in *silicon-manganese* spring steels, due to its effect in raising the limit of proportionality, and up to 4% in heat-resisting steels owing to its ready oxidation assisting the formation of a protective layer. The higher the silicon, the higher the temperature at which protection against further atmospheric oxidation is given. Water vapour and carbon dioxide, however, attack the layer. Alloys of iron and silicon, containing 15% of the element are used as acid-resisting materials, but have the properties of cast irons rather than of steels. Carbon-free alloys with up to 4% silicon have a high electrical resistance and low hysteresis loss, and are used as transformer steels. In cast iron, silicon not only serves as a deoxidizer but also has a marked graphitizing effect. Silicon tends to soften cast irons, thereby improving machinability and providing a control over depth of chill and physical properties. Siliconized coatings on iron and steel confer increased resistance to certain forms of corrosion. (See IHRIGIZING.)

Silicon Acid Resisting Iron. (See SILICON.)

Silicon Carbide. (*SiC.*) Specially processed silicon carbide is available for use as a deoxidizing agent in basic electric steelmaking. It is claimed that because of the initial reducing atmosphere which occurs with silicon carbide addition, it is possible to shorten the finishing period appreciably and to produce a steel at least equal in quality to one made under a *calcium carbide* slag. (See also CARBORUNDUM.) (L. 49.)

Silicon Fur. A type of scale which forms on certain kinds of high silicon steel sheets, i.e. transformer sheets, after annealing. It is characterized by its poor adhesion to the metal, abnormal thickness, and the fact that it is less acid soluble than ordinary scale. (G. 71.)

Silicon Manganese. (See SILICO-MANGANESE.)

Silicon Manganese Steels. (See SILICON.)

Silicon Steel. (See SILICON.)

Silicone-Aluminium Coatings. It is claimed that silicone-aluminium paints will withstand any temperature where structural considerations permit the use of mild steel, i.e. up to and including about 540° C., and thus lengthen the life of mild steel parts subjected to such temperatures or to intermittent brief exposures to much higher temperatures. Silicone-aluminium coatings are also recommended for the protection of stainless steel when used continuously in the 760° to 870° C. range.

Silicones. Heat stable compounds of silicon in which the silicon atoms are linked up by oxygen atoms, the remaining valencies of the silicon atoms being saturated with hydrogen or organic radicals. Silicones with widely varying properties can be produced. They are chemically inert. In the foundry they are used as bonding agents for moulding and core sands, as moulding facing materials, as plasticizers for the flexible moulds used with low melting alloys,

and as sealants for the pores of metallic coatings. They are also used as water-resistant films, as lubricating oils and greases, as resin for electrical insulation, as synthetic rubber, and in heat-resisting paints.

Siliconizing Process. The method of producing a heat-resistant adherent coating which is gas- or vapour-tight and fast sticking on a body formed of a metal or alloy of high melting point (such, for example, as the metals, molybdenum, tungsten, tantalum, niobium, chromium, platinum, iridium, osmium, or their alloys) which consists in first coating the metal or alloy with a silicon alloy having a silicon content of at least 15% and oxidizing it to form a primary layer of heat resistant oxide, superimposing on the primary layer a secondary layer of material containing silica and finally applying heat to cause the material of the secondary layer to melt and form an external glaze. (See also IHRIGIZING.) (M. 133.)

Siliflex Process. A method of hot galvanizing, similar to the *Crapo process*. It is claimed to provide an excellent zinc coating without detriment to the mechanical properties of the steel base.

Silklay. A finely ground plastic fireclay of high refractoriness used as a bond for moulding sands.

Silky Fracture. A steel fracture having a very smooth fine grain or silky appearance.

Silky Pig Iron. High silicon iron with bright glazed fracture.

Sill. The term as applied to a furnace refers to the horizontal structure forming the base of the door in the furnace wall.

Sillimanite. An aluminium silicate having a high softening point (over 1800° C.); high stability up to its actual softening point; low coefficient of expansion; freedom from volume changes; neutral reaction; great resistance to the corrosive action of many slags and abrasion of moving charges; equal efficiency in either oxidizing or reducing atmospheres; great strength, maintained up to a softening point; very high electrical insulation at low frequencies and at temperatures up to 1000° C., together with moderately high thermal conductivity. (I. 76.)

Silt. Very fine sand particles.

Silver. (*Ag.*) *Atomic weight* 107·88. *Melting point* 960·8° C. A pure white metal capable of receiving a brilliant polish. It is extremely malleable and ductile, although less so than gold. In an annealed condition, it is the best conductor, both of heat and electricity, known. As cast it has a *specific gravity* of 10·50 which on cold working is increased to 10·57. "Fine" silver, which is the commercially pure form of the metal, is too soft for most purposes, and therefore it is usually alloyed with copper. "*Sterling silver*", which is hall-marked in Great Britain and was the legal standard of British coinage from the time of Queen Elizabeth I until 1920, contains 7·5% copper. The addition of 0·2% to 3·0% silver to austenitic corrosion-resisting steels of the 18/8 chromium nickel type was the subject of a German patent application in 1932, and in 1943 a die steel containing 2% silver was patented in the U.S.A., but no commercial use has been made of silver as an alloying addition to steel. (Cf. SILVER STEEL.)

Silver Brazing Alloys. (*Silver Solders.*) These are usually ternary alloys of silver, copper and zinc, e.g. a soft silver solder contains 67% silver, 20% copper and 13% zinc. A typical hard silver solder consists of 80% silver and 20% copper, the silver being added to lower the melting point of the solder and increase its fluidity, whilst still retaining high strength. Certain silver brazing alloys may contain other metals such as cadmium or tin.

Silver Finish Sheet. Severely cold rolled bright annealed sheet.

Silver Ply Steel. A proprietary name for a clad steel in which a thin layer of stainless steel is bonded to a base of mild steel. There is no silver in the composition.

Silver Solder. (See SILVER BRAZING ALLOYS.)

Silver Steel. (*a*) A name given to bright drawn carbon steels, containing about 0·95% to 1·25% carbon with low sulphur and phosphorus and normal silicon and manganese. It has no silver in its composition. (*b*) (See SILVER).

Silver Tin. Tin-plate having a dull surface intentionally produced by mechanical treatment of the underlying steel.

S.I.M.A. Scientific Instrument Manufacturers Association.

Simons Mill. A mill for the cold reduction of steel strip. It consists of a 4-high stand with steel working rolls 1¼ in. in diam. and cast iron backing rolls 8 in. in diam. The novel feature of the mill is that the upper and lower pair of rolls are given a reciprocating motion of 3 in. in opposite directions and transverse to the rolling direction. The backing rolls are driven by a 35 h.p. motor, and the work-rolls by the friction from the former. The strip is pulled through the rolls at 500 to 600 ft. per minute—a speed which is greater than

the surface speed of the working rolls—the strip is thus drawn as well as rolled. The small diameter of the working rolls makes the entrance angle for the strip a large one, and the strip is not hardened as much as it would be by rolls of greater diameter. It is therefore possible to make larger reductions in each pass and a very large total reduction in the strip thickness without intermediate annealing. (P. 21.)

Simplex Process. A process for the production of ferrochrome having a carbon content of less than 0·025%. In the key operation, carbon and silica react at about 1093° C. and under vacuum. This converts the carbon to carbon monoxide. The reaction takes place in a horizontal cylindrical furnace about 12 ft. in diam. and 150 ft. long. Carbon resistors in the upper part of the cylinder radiate heat to a charge of briquetted alloy in a bed of about 12 in. thick. Feed for the Simplex process, is ferrochrome produced in a standard arc furnace. It is ball milled to a fine powder, mixed with a small amount of sand, and pelletized in a roll briquetting press. (C. 24.)

Simultan Deep Drawing. A process in which the ram is surrounded by two concentric sleeves and the dies consist of corresponding concentric sleeves. Each ram and die has its own independently controlled hydraulic cylinder which enables the three stages of drawing to be accomplished in sequence without interruption. (O. 2.)

Sincosite. ($CaO.V_2O_4.P_2O_5.4H_2O$.) A vanadium ore.

Singer Process. A process in which a phosphate coating is applied to steel articles before they are cold worked, especially before drawing. The main advantages claimed are that intermediate annealing can be dispensed with and that the tools and dies have a long life. (F. 1.)

Single-Acting Hammer. A forging hammer in which the head is raised by a steam cylinder and piston and the blow is delivered by the free fall of the head. (A. 27.)

Single-Action Press. A forming press that operates with a single function, such as moving a punch into a die with no simultaneous action for holding down the blank or ejecting the formed work. (A. 27.)

Single Bead Weldability Test. The test consists of depositing a single bead of weld metal 3 in. long down the centre of a plate 9 × 3 × ½ in. sectioning the the plate transversely at a distance of 1 in. along the bead from its starting point and making a hardness survey of the heat affected zone; if at any point the hardness exceeds Brinell 350, the steel is not readily weldable under the conditions of the test. (M. 71.)

Single Bend Test. (See BEND TEST.)

Single Crystal. A mass of metal in which the whole conforms with a uniform *orientation* as distinct from a *polycrystalline* mass. Single crystals can be grown direct from the liquid by arranging the solidification to start at a constricted point or line so that only a single nucleus forms, and then to continue regularly into the mass of liquid by passing the mould through a temperature gradient. They can be formed in the solid state by critically straining the metal in the form of strip or rod and then *annealing* under suitable conditions. They have been largely used in studying fundamental problems relating to the deformation and failure of metals. When single crystals are deformed under *stress*, *slip* occurs along one of a set of crystallographic planes (generally a plane of highest atomic density) and along a definite direction within that plane. Hence the dimensions of the cross-section change considerably in one direction but not in others.

Single Cut File. (See CUT.)

Single-Impulse Welding. The making of spot, projection and upset welds by a single impulse of current. When alternating current is used, an impulse may consist of a fraction of a cycle or a number of cycles. (A. 37.)

Single Lap. (See TEEMING LAP.)

Single Phase Material. A material consisting of a completely homogeneous structure.

Single Potential. (See ELECTRODE POTENTIAL.)

Single Shear Steel. (See CEMENTATION.)

Singles. Sheets which have been hot rolled separately.

Sink. (*a*) The operation of machining impressions into forging dies. (See DIE SINKING). (*b*) (See DRAW).

Sinkhead. (See FEEDER HEAD.)

Sinking. A term used in the production of cold finished tubes when the tube is pulled through the die without internal support: By this means the wall thickness is increased whilst the tube is increased in length and reduced in diameter. (See also DIE SINKING.)

Sinking Mill. A mill in which tubular products are reduced by *sinking*.

Sinking Rollers. Rollers used to direct wires below the surface of the spelter bath during galvanizing.

Sinter. (See SINTERING.)

Sintered Metal Carbide. (See HARD METALS.)

Sintered Stainless Steel. (See STAINLESS STEEL POWDER.)

Sintering. (*a*) The process of agglomerating fine iron ore and iron-bearing materials, such as *mill scale*, with coke breeze, so that they may be charged into the blast furnace without choking it and impairing its efficiency by impeding the upward flow of gases. (*b*) The bonding of adjacent surfaces of particles in a mass of *powder* or a *compact* by heating to a suitable temperature depending upon the metal concerned, keeping the compact at that temperature for a predetermined time, and then cooling it.

Sintering Point. (*a*) In castings, that temperature at which the moulding material begins to adhere to the casting. (*b*) In sand, that temperature at which the sand coheres to a platinum ribbon under controlled conditions. (A. 26.)

SiO_2. *Silica.*

S.I.S. The prefix of steel specifications issued by Sveriges Standardiseringskommission, Stockholm, Sweden.

Size. (*a*) Dimension. (*b*) The operation in a *coining* press to obtain closer tolerances on portions of the forging. (*c*) Powdered glue.

Size Fraction. A separated fraction of a powder whose particles lie between specified upper and lower size limits. (G. 30.)

Sizing. (*a*) Primary coating of very thin glue. (*b*) The process of attaining the desired dimensions of a part by any finishing operation. (*c*) A process of squeezing under a heavy press. It is used for flattening or surfacing parts where only a very small amount of flow in the material is involved. Very close tolerances can be obtained by this process. (*d*) In the production of tubes, the operation of passing them through a series of sizing rolls to attain accuracy of external shape and section. (*e*) (COINING).

Sizing Die. A *die* used for the *sizing* or *coining* of a sintered compact. (G. 30.)

Sizing Knockout. An ejector punch used for pressing or ejecting a sintered compact during the *sizing* operation. (G. 30.)

Sizing Punch. A punch used for pressing of the sintered compact during the *sizing* operation. (G. 30.)

Sizing Stripper. A stripper punch used during the *sizing* operation. (G. 30.)

Skeleton. In sand moulding, a metal framework on which a flat *core* is built.

Skeleton Pattern. A framework representing the interior and exterior form and the metal thickness of the required casting. (A. 26.)

Skelp. Mild steel strip, often produced from Bessemer steel, from which tubes are made by drawing through a *welding bell*, at welding temperatures, to produce *butt*, or *lap welded* tubes. The skelp is made of a suitable width and thickness to form a tube of the required diameter and wall thickness.

Sketch Plates. Plates cut to shapes other than rectangular. (See SKETCHING.)

Sketching. In plate mills, the marking of plates so as to indicate where they are to be sheared.

Skew Roller Table. A roller table in which the rollers are set at an angle, i.e. on the skew. The method of setting the rollers enables the bar to be moved diagonally across the table as it is moving forward.

S.K.F. Slag Inclusion Scale. (*Hofors Slag Inclusion Count.*) A comparative scale for the numerical estimation of the amount of slag inclusions of the plastic sulphide type and the brittle oxide slags. It is prepared as follows: A ½ in. disc is hot-sawn from the middle of a billet, approximately 4 in. square, rolled down from selected ingots. A length section is prepared and examined from the centre to the surface under a microscope at a magnification of 100 diameters. The scale is numbered from 1 to 4 but covers a narrower range than the *Jernkontorets* scale, and sections in ball-bearing steel, rated according to Jernkontoret, would give a numerical value approximately 0·5 less than the Hofors scale. The numerical values given for slag rating in steel cannot, of course, be exact, because the composition of the inclusions and the number and dimensions of slag inclusions vary from section to section and from ingot to ingot. A dispersion in numerical values of $\pm$ 0·5 may, therefore, occur. (S. 153.)

Skiagraph. (See RADIOGRAPH.)

Skim Bob. A small upward bulge in the ingate of a sand mould, an inch or two from the casting, which acts as a dirt trap.

Skim Cores. *Cores* set in *skim gates* to act as *skimmers*. (P. 1.)

Skim Gate. A *sprue* so arranged as to skim impurities from the surface of the molten metal as it flows into the *mould* and so prevent them from entering the mould. (P. 1.)

Skimmer. A tool for removing scum and *dross* from metal. (A. 26.)

Skimmer Brick. A brick placed on the surface of metal in a *ladle* to hold back *slag*, etc.

Skimmer Core. (See STRAINER GATE.)

Skimming. Holding back from a casting the dirt, slag or skim in the molten metal before or during pouring. (A. 26.)

Skin. A thin surface layer that is different from the main mass of a metal object in composition, structure or other characteristics. (A. 26.)

Skin Blowhole. (See SUBCUTANEOUS BLOWHOLE.)

Skin Drying. The process of drying the surface of a green sand *mould* to a depth of an inch or more, by direct application of heat. It is general practice to spray a binding material on to the face of the mould before drying.

Skin Effect. The concentration of alternating current in the outer layers of solid conductors. This effect is very marked with very high frequencies when the current may be practically confined to the surface.

Skin Hole. A hole which is visible on the surface of an ingot as distinct from a *subcutaneous blowhole.*

Skin Milling. Synonymous with *Chem-Milling.*

Skin Pass. A very light reduction given by cold rolling heat treated sheet or strip in order to prevent the formation of *stretcher strain markings,* and the tendency to *kinks* or *flats* on subsequent working.

Skin Passed. (*Non-Kinking, Non-Flatting, Pinch Passed,* or *Killed Sheet.*) Sheet or strip which has been subjected to a *skin pass.*

Skin Segregate. (*Rim Segregate.*) The outer zone of a rimming steel ingot differing in composition from the *core.*

Skinning Loam. (See SLIP.)

Skip Sequence. (See WANDERING SEQUENCE.)

Skip Hoist. A basket, bucket, or other container which may be drawn or elevated on rails by a pulling action. Used chiefly for charging materials into the cupola or blast furnace. (A. 26.)

Skip Welding. A technique devised to minimize warping in the fabrication of naval cartridge case chutes from high tensile formed steel plate and stainless steel bars. By welding about 5 in. in one locality and then "skipping" across to a corresponding opposite area of the chute, depositing a like bead and always laying a new bead in the opposite direction of the old one, it is possible to spread out the total heat more evenly and dissipate much of the effect of stresses occasioned by welding processes. (H. 35.)

Skoda-Sawin Wear Testing Machine. The working tool of this machine is a smooth rotating disc of tungsten carbide 30 mm. in diam. and 2·5 mm. wide, which under a constant load, grinds an impression in the fixed test piece. The volume of the impression ground on the specimen is calculated from measurements made by a depth gauge on the machine, and this is a measure of the wear-resisting properties of the material. (E. 23.)

S.K. Porosity Test. (*South Kensington Test.*) A rapid method of testing the porosity of ores. The principle of the test is to fill the voids in turn with mercury, air and water; for porous materials the voids are greatest for air, less for water, and least for mercury. The differences between the values are a measure of the porosity relative to the fluids employed. (S. 13.)

Skull. (*Kish, Ice, Frost.*) (*a*) Solidified metal remaining in the melting furnace or ladle after the steel has been tapped or cast, or in the spoon after taking a spoon sample. (*b*) An oxidized film which may be formed on the surface of steel on teeming into the mould.

Skull Melting. (See REM CRU SKULL MELTING.)

Skull Patch. An internal defect in a steel ingot due to the trapping of an oxidized film of metal during teeming into the *mould.*

Skutterudite. A rare mineral, consisting of cobalt arsenide, $CoAs_3$, found in Norway. (Cf. SMALTITE.)

SLA. Special Library Association. (U.S.A.)

Slab. A semi-finished hot rolled product worked down from the ingot following the stage of the bloom but distinguished from the billet by its flat section. It has a minimum thickness of 1½ in. and a width generally more than twice the thickness. It is intended for further rolling into plate, sheet, strip, or other flat products.

Slab Core. A flat plain *core.*

Slab Pile. In the manufacture of wrought iron, a pile built up wholly of flat bars of iron, all bars running the full length of the pile. (See PILING.)

Slab Shear. A hydraulic shear for cutting slab into lengths for further rolling.

Slab Turner. A device for turning a slab so that it may be cross rolled in the *blooming mill.* It consists of two hydraulically operated pistons positioned one above and one below the table in such a manner as to operate between the table rollers. The slab itself sets the device in motion by passing over a shoe which operates a trip mechanism.

Slabbing Mill. A rolling mill in which *ingots* are rolled down to *slabs.*

Slack Quenching. Quenching a steel in such a fashion that it is not completely martensitic but contains *ferrite* or *bainite* together with the *martensite.* Such a condition may result, for ex-

ample, from quenching steel from a temperature above the transformation range to a temperature well below the transformation but substantially above room temperature, or by oil quenching or by exceeding the limiting ruling section at which full hardening is attained.

Slag. (*Cinder, Scoria.*) (*a*) In the blast furnace, the molten non-metallic layer formed by the reaction of the flux and the gangue of the ore, which floats on the surface of the molten pig iron. (*b*) The non-metallic layer covering the molten steel in a steelmaking furnace. It is formed from the materials, e.g. lime and ore, added for the purpose of assisting purification and thus is a complex mixture of silicates holding in solution varying quantities of different oxides. It plays an important part in the refining of steel for it not only controls the temperature of the metal, but must supply the oxidizing reagents to enable the reactions to take place at the desired speed and time, and further, has to incorporate the oxidized products in a form which will not be reacted on by the metallic iron towards the end of the process. An *acid slag* consists principally of silica, whilst a *basic slag* is composed chiefly of lime or oxide of iron.

Slag Basin. A space provided to collect the *slag* produced in *thermit welding*.

Slag Clouds. Sub-microscopic non-metallic inclusions. (M. 145.)

Slag-Gas Shielded Welding. A manually applied, semi-automatic arc-welding process in which the flux is contained within the tubular electrode. As the metal of the electrode is melted by the heat of the arc, to become part of the weld metal, the flux core also melts and becomes the refining and shielding blanket of slag. In order to prevent oxidation of the electrode materials while transferring through the arc, a separate gas is used for shielding the arc column, the welding current, the shielding gas, the cooling water, and the welding electrode all passing through the handle of the torch.

Slag Hole. (*a*) An opening in the back of a *cupola* through which the slag is drawn. (*b*) An opening in the *blast furnace* for the removal of slag. This is usually known as the *cinder notch*.

Slag Inclusion. Non-metallic solid material entrapped in the solid steel. (See NON-METALLIC INCLUSIONS.)

Slag Patch. Slag which has been trapped under the surface of a steel ingot during freezing.

Slag-Print Process. (See NIESSNER SLAG PRINT PROCESS.)

Slag Shortness. Brittleness due to the presence of slag in the solid material.

Slag Stringer. An elongated *slag inclusion*.

Slag Top. A variation of the *hot top*.

Slag Wool. (See MINERAL WOOL.)

Slagging. (*a*) The removal of the layer of slag from a steel bath. (*b*) In the U.S.A., the reaction between the furnace refractories and external reagents resulting in the formation of a molten liquid slag.

Slaked Lime. Calcium hydroxide ($Ca(OH)_2$), formed by the action of water on quicklime, CaO.

Slaking. The addition of water to quicklime to form *slaked lime*.

Sledge. A large cast steel plate set underneath the bottom roll in a rolling stand, to facilitate roll changing. In large modern mills this is effected by sliding the two rolls through the *windows* of the *housing*. To do this the top roll is lowered on to the bottom roll and the *screw down gear*, pinions, etc., are disconnected, thus permitting the sliding out of the rolls on the sledge.

Sleeve Bricks. (See LADLE.)

Slenderness Ratio. (*a*) Length of the tensile test specimen divided by the square root of the cross-sectional area. (*b*) The ratio of the length divided by the least radius of gyration about the *centroid* of the section; used in connection with the stability of struts.

Slicker. A thin flat steel tool used for smoothing the surfaces of moulds.

Slicker Solder. (See PLUMBER'S SOLDER.)

Slicking. Smoothing the surfaces of *moulds*.

Slidabrading. A process for finishing metal or plastic parts by tumbling in a rubber-lined drum filled with an abrasive medium which may be alumina or granite fragments in water.

Slime. Material of extremely fine or colloidal particle size, encountered in ore treatments, and electrolytic refining. (See ANODE SLIME.) (A. 27.)

Sling. (See BEAM AND SLING.)

Sling Shot Impact Testing Machine. A machine for the investigation of plastic strain in long wire. The specimen of wire approximately 80 in. long × 0·100 in. diam. is held vertically, the lower end being attached to a tup and the upper end being rigidly clamped and passing through the centre of a hollow hammer operating on rails. The hammer is raised to the desired height or to the extension of the rubber bands which are attached to the frame of the machine and the hammer, and then released, being accelerated downwards by the rubber bands and finally striking the tup. Both the tup and the hammer then move downwards pulling the wire

until the latter reaches the anvil which has been placed in a position to give the desired duration of impact. At this point the outside of the tup is sheared off and the hammer is allowed to continue downwards inside the hollow anvil until the kinetic energy of the wire has been dissipated in strain energy. (D. 54.)

Slip. (*a*) A term used when the rolls fail to grip the surface of a piece which is being rolled. (*b*) *Glide*. The mechanism of cold deformation wherein one part of a crystal glides over another part along certain planes known as *slip planes*. (*c*) (*Skinning Loam*). The wash applied to the surfaces of *loam* moulds. (*d*) (See SLIP CASTING).

Slip Bands. (*Slip Lines, Slip Planes.*) A series of parallel lines showing across the individual crystals of a deformed polished surface, and caused by the block-like movements within metallic crystals along geometrically disposed lines. It is this phenomenon which confers on metals the properties of ductility, plasticity and malleability.

Slip Casting. In ceramics the *slip* consists of an aqueous suspension of finely ground clay, which is poured into a plaster-of-Paris mould. As the plaster-of-Paris absorbs the water from the slip the latter solidifies and shrinks against the mould and the casting is taken from the mould, dried and fired. (T. 20.)

Slip Crack. (*Pressing Crack.*) A rupture in the pressed compact, caused by the mass slippage of a part of the compact.

Slip Direction. Direction of *slip* in an individual crystal.

Slip Interference. In a ductile metallic structure, resistance to deformation offered by a hard phase dispersed in the matrix.

Slip Jacket. A frame to place round a *snap flask* after the flask is removed. (A. 26.)

Slip Lines. (See SLIP BANDS.)

Slip Planes. (See SLIP BANDS.)

Slip Plane Precipitate. A precipitate formed from solid solution, preferentially along planes on which slip has occurred, as a result of quenching stresses or cold working after solution heat treatment.

Slips. Irregularities in *blast furnace* practice caused by wedging of the *stock* in the upper part of the stack.

Slit. In X-ray metallography and spectroscopy, a narrow opening with parallel sides, used to define a beam.

Slit Edge. (See EDGE CONDITION.)

Slit Gate. (See VERTICAL DOUBLE PILLAR.)

Slit System. In X-ray metallography, a series of *slits* used to define a beam and to shield against secondary X-rays.

Slitless Spectrograph. (See WEDGE SPECTROGRAPH.)

Slitting. The operation of cutting strip into still narrower lengths by the action of a rotary cutter.

Sliver. (*Spill.*) A thin piece of metal projecting from the surface of an ingot. (Also known as *fin.*)

Slot Weld. A weld made in a slot formed in one of the parts of a *lap joint.*

Slug. A term used in *drop forging* for a length of *bar* or *billet* of the size required for a single *drop forging.*

Slug Test. (*a*) A test for the quality of a *spot weld* in which two pieces of steel spot welded together are prised apart in such a manner that slugs of metal are pulled from one or other of the welded sheets. The usual requirement of this test is that the slug pulled out when the last test weld is prised open shall be above a certain minimum diameter. (*b*) (See UPSETTING TEST).

Slugging. The act of adding a separate piece or pieces of material in a joint before or during welding, resulting in a welded joint which does not comply with design, drawing or specification requirements. (A. 37.)

Slurry. A thin paste made by mixing certain finely ground materials, such as cement, with water. It is used, for example, to fill in the joints of a *core.*

Slurrying. The process of filling in joints with *slurry.*

Slush Casting. The mould used is essentially the same as the gravity die, with a runner as an open orifice on the top face. When the mould is filled it is given a few seconds to chill and then is inverted (or nearly inverted) so that the liquid core of the casting is poured away. By this operation a shell is formed, and when the mould is taken down, the casting, which possesses a good external finish, is removed.

Slushing Compound. A non-drying oil, grease, or similar organic compound which, when coated over a metal, affords at least temporary protection from corrosion.

Sm. Chemical symbol for *samarium.*

Smalley Process. A method for desulphurizing iron and steel with metal hydrides in which a molten slag is floated on a mass of molten ferrous metal and at least one metal hydride is introduced into the mass. The molten ferrous metal is separated from the slag, the metallic hydrides breaking down into metal and nascent hydrogen. Hydrides of the alkali metals have been found very satisfactory and are readily available. (S. 78.)

Smaltite. A cobalt ore which consists essentially of cobalt diarsenide ($CoAs_2$)

together with some iron, although usually it contains a considerable proportion of nickel. If the nickel content predominates the mineral becomes *chloanthite*. No clear line can be drawn between the two minerals, one merging into the other according to the nickel and cobalt contents.

Smeaton, John, F.R.S. (1724–92.) The Yorkshire inventor of cast iron tight fitting blowing cylinders, about the year 1768. In blowing apparatus, this constituted the first important improvement on the bellows.

Smelting. A metallurgical process, or series of processes, whereby a metal or compound is separated in a state of fusion from its ore or other material with which it is chemically combined or physically mixed. The separation of the impurities which are highly refractory involves the fusion of the ore with suitable fluxes to produce a melt consisting of two layers, the molten metal sinking to the bottom, whilst the *gangue*, together with the flux, forms a slag which floats on the top. (See BLAST FURNACE.) Care should be taken to distinguish between the terms smelt and *melt*.

Smialowski Apparatus. A recording microphotometer, by means of which the reflectivity of a very small area of a specimen can be measured and the non-metallic inclusions in steel, or cast iron, determined. It comprises a small metallographic microscope, a selenium photoelectric cell, a light source, a galvanometer and a registering drum. (S. 80.)

Smidth Agglomerating Kiln. A rotary kiln providing an alternative method to *sintering* for the treatment of fine ores and flue dust. (S. 68.)

Smith Forging. (*a*) (*Hand Forging*, or *Flat Die Forging*.) Forgings made by hand on an anvil or under some power hammer without the use of dies. Such forgings approximate each other in size and shape but lack the dimensional precision of die forgings. (*b*) The operation of producing such forgings.

Smith Hammer. Any hammer used in *smith forging*.

Smith Process. A process for the production of sponge iron, which is carried out in vertical ovens or retorts, similar to coke ovens in design. The crushed ore or iron oxide material is mixed with carbonaceous material and charged into the oven, where it is heated and cooled by means of horizontal flues. It is preheated in the upper part of the oven by the waste gases, which leave the stack at about 200° C. The charge then enters the reduction zone, where temperatures range from about 870° to 1095° C. and is subsequently cooled by the incoming air for combustion in the heating flues, being discharged at less than 120° C. (W. 12.)

Smith - Stringfellow Wire - Drawing Block. A block for applying a back pull to the wire passing through a wire drawing die. With it the back pull is not maintained at a constant value, but the ratio of the back pull to the forward pull is constant and the load imposed on the die automatically determines the amount of back tension. It is claimed that the use of this drawing block increases the life of the die and produces wire with uniform physical properties. (S. 149.)

Smith Wear and Lubricant Testing Machine. In this machine, a hardened steel ball 1 cm. diam. is rotated at high speed on a horizontal axis whilst a specimen of the metal under test is pressed against the rotating ball by means of a weight. The specimen is flooded with oil and the effect of the rubbing action is to produce a spherical impression, the diameter of which increases at first comparatively rapidly and then at a diminishing rate until the increase eventually becomes imperceptible. This diameter is measured as in a Brinell test. By repeating the tests with the same metal but with different lubricants the latter can be compared (E. 46.)

Smith-Welding Process. A fusion operation in a reducing atmosphere which is stated to eliminate oxide inclusions and other impurities from the weld, leaving a metal of greater refinement than that of the weld joint. It is claimed that the tensile strength of the Smith weld is greater than that of the adjoining metal.

Smith's Fatigue Testing Machine. A machine devised for applying alternating direct stresses operating at a speed of 1000 r.p.m. The upper end of the specimen is attached rigidly to the frame of the machine, the lower end being fixed, by means of a bearing, to a shaft carrying two discs each of which rotates in a vertical plane and supports an unbalanced weight. Any desired mean stress (tension or compression) can be superimposed on the alternating stress by means of a spring and hand wheel attached at right angles to the shaft. (E. 35.)

Smoking. A phenomenon sometimes observed during wire drawing when smoke appears to come from the wire. The smoke may be light or dark in colour and may be due to the presence

of occluded hydrogen or to inefficient cleaning of the wire.

S.M.R.E. Safety in Mines Research Establishment, Sheffield.

Smudge. A paste used for the protection of certain areas during surface treatment, when it is desired that these areas shall remain unaffected by that treatment.

Sn. Chemical symbol for *tin*, from the Latin *stannum*.

S-N Curve. *Stress-number curve* showing the number of reversals to rupture for a given applied stress in a *fatigue test*.

Snagging. The removal of *sprues*, *fins*, etc., from steel castings by grinding.

Snap Flask. (See FLASK.)

Snarl. A kink in a length of wire which has been pulled tight.

Snarl Test. A test for wire, in which the wire is looped, pulled taut and straightened, the operation being repeated until fracture occurs.

Snatch Box. A guide box designed to hold the guides in position in a rolling mill, where one of the guides is adjustable, i.e. it can be moved laterally inside the guide box. By this method the grip of the guides can be controlled, thus preventing any sticking in the guides. This device overcomes the difficulty often experienced in entering bar through the guides.

S.N.D.T. Society for Non-Destructive Testing.

Snell's Law. (See INDEX OF REFRACTION.)

Snelus, George James, F.R.S. (1837–1906.) An English metallurgist who in 1872, took out a patent for the use of lime for lining the Bessemer converter, on the principle that lime would not react with a basic slag and would eliminate phosphorus. The invention did not come into commercial operation until after the work of Thomas and Gilchrist, but the part which Snelus had played in developing the process was acknowledged by the Iron and Steel Institute, when he was awarded the Bessemer Gold Medal jointly with Sidney Thomas.

Snow. (See CARBON DIOXIDE.)

Snowflakes. (See FLAKES.)

Soaking. Holding the steel, e.g. a steel ingot, at an elevated temperature to secure uniform temperature throughout the mass or to promote diffusion, thus dispersing segregation and obtaining a more homogeneous structure.

Soaking Pit. Originally just a crude, heat-retaining firebrick-lined hole in the ground. The pit was for soaking the ingots or permitting the heat contained in the still molten steel in its interior to penetrate to the outer portions until the temperature of the entire ingot was reasonably uniform. Then with the aid of wall radiation and light firing, the ingots were rapidly brought into a satisfactory condition for rolling. Modern soaking pits are of four designs: (1) The regular reversing regenerative type of pit which operates in much the same way as the *open hearth furnace*. (2) The one-way fired recuperative pit where the flame enters at one end and leaves the pit at the same end but at a lower level. (3) The bottom-fired recuperative pit where the flame enters from the bottom and (4) the tangentially-fired circular pit where the flame enters tangentially. (G. 20.)

Soap Drawn Wire. Wire in which soap has been used as the lubricant in the drawing operation.

Soap Lubricants. These include the so-called *metallic-* and *sodium-soaps*. The former consist of aluminium or calcium alkaline materials compounded with a suitable fatty acid whilst the sodium soaps consist of mixtures of caustic soda or soda ash and a fatty acid. It is said that the use of such lubricants in wire drawing prolongs the life of the dies, whilst the fact that they are water repellent tends to protect the stock from corrosion.

Soaping Out. A combination of free fatty acid and lime, producing an insoluble soap formed on wet drawing after liming.

Soaps. (See PUPS.)

Soapstone. (See TALC.)

Societies. (See Appendix V.)

Socket. (See SPIGOT.)

Soda Ash. Commercial sodium carbonate. It has been used as an addition agent for the desulphurizing of *hot metal* in the ladle. (See SODIUM CARBONATE.)

Söderberg Electrode. A continuous self-baking electrode. The requisite constituents, i.e. anthracite, coke, pitch and tar, are prepared and packed into an internally ribbed cylindrical container. This is arranged with the lower end projecting into the furnace, the heat of the furnace transforms the mixture into a good-quality carbon electrode continuously as the cylinder is allowed to descend slowly into the furnace. (W. 6.)

Sodium. (*Na.*) A metallic element in the first group of the periodic system, one of the alkali metals. Atomic number 11. *Atomic weight* 22·991. *Melting point* 97·7° C. *Specific gravity* 0·79.

Sodium Benzoate. An effective inhibitor of the corrosion of mild steel in water and very dilute (e.g. 0·03%) NaCl solutions. The concentrate of benzoate required for inhibition is greater for

machined than for emeried surfaces and for mains water or chloride solutions as compared with distilled water. It is a safe inhibitor, since it does not lead to intense local corrosion when the concentration is just below the minimum required for protection. The following benzoates also possess inhibitive properties; potassium, lithium, zinc, and magnesium. (W. 71.)

Sodium Bisulphite. An etching reagent for ferritic steels. A solution of 60 ml. $NaHSO_3$ and 40 ml. H_2O is used at 30° C. for selective attack of the ferrite which takes on a uniform maroon colour. The solution is particularly useful for the examination of magnetic silicon steels after annealing and 18–4–1 high-speed steels after isothermal quenching. Higher concentration of $NaHSO_3$ decreases contrast in the etched surfaces. (B. 28.)

Sodium Carbonate. (Na_2CO_3.) This alkali has been used as a ladle addition for refining hot metal, with the object of reducing the sulphur content and eliminating sulphide segregation, to minimize porosity, and remove non-metallic inclusions. The process is usually known as the *Soda Ash* treatment.

Sodium Cyanide Metallographic Etch Test. A method for revealing precipitated carbides in the 18–8 type stainless steels, which if properly used will reveal carbides without attacking austenite or crystal boundaries. The test is applied to 18/8 in any condition, e.g. after hot- or cold-working, or welding, or after exposure to corrosive media. Specimens are polished, immersed in a 10% solution of sodium cyanide in water, and electrolytically etched in preparation for examination under the microscope, usually at a magnification of 500. Carbides, when present, appear as black lines or globules in an otherwise unetched surface. (A. 53.)

Sodium Hexametaphosphate. (See CALGON.)

Sodium Hydride. (NaH.) The compound attained on heating metallic sodium in hydrogen. It finds application in modern strip mills as a descaling agent for hot rolled strip.

Sodium Hydride Descaling. The process consists of immersing the metal in a bath of molten caustic soda containing about 2% of sodium hydride for slightly longer than is taken to attain the same temperature as the bath (about 370° C.), then removing the metal from the bath, quenching in cold water, and finally swilling in hot water. It is claimed to have many advantages over acid *pickling*. Scale or oxide only is removed, and there is no action on the parent metal. The molten caustic, being very fluid, readily covers all surfaces, which ensures that the inside surfaces are cleaned as well as the outside. The process is very rapid, and it is claimed that hydrogen embrittlement is impossible. (M. 123.)

Sodium Hydride Desulphurization. (See SMALLEY PROCESS.)

Sodium Hydroxide Desulphurization. In this method, the molten iron to be desulphurized is tapped into an open-top conventional ladle, solid sodium hydroxide being simultaneously added at intervals during the tap. The sodium hydroxide melts, forming the desulphurizing slag, a rather violent reaction causing the desulphurizer to foam. Although some desulphurization takes place in the ladle, the main function of this part of the operation is to melt the sodium hydroxide and bring it up to metal temperature and eliminate the undesirable foam. When this point is reached, the contents of the ladle are poured into a second ladle at such a rate as to cascade the metal and the previously conditioned desulphurizer into the second ladle, where the bulk of desulphurization takes place. When reladling is completed, the desulphurizer is removed. (I. 60.)

Sodium Nitrite. ($NaNO_2$.) This salt has been used with success in concentrations of 0·1% glycol containing 1·5% sodium benzoate as a corrosion inhibitor. (W. 72.)

Sodium Silicate. (See WATER GLASS.)

Sodium Soap. (See SOAP LUBRICANTS.)

Soft. In X-ray metallography, having little penetrating power, long wavelength, low frequency. (A. 26.)

Soft Drawn Wire. (See MILD DRAWN WIRE.)

Soft Gap. In *argon arc welding*, the condition of the gap after arc extinction in which there appears to be appreciable remanent conduction, thereby modifying the restriking voltage and possibly the arc re-ignition process.

Soft Skin. A thin surface layer of decarburization. High speed steel is particularly susceptible to this defect owing to the high temperatures required for hardening.

Soft Soldering. Soldering with a low temperature jointing alloy. The most widely used alloy contains about 60% lead and 40% tin, and has a melting point of 180° C. Tin is added to lower the melting point as required. Occasionally, other elements such as antimony may be included with the object of lowering the melting point.

Soft Steel. *Mild steel.*
Soft Temper. (See TEMPER.)
Softening. A process effected by *annealing* or *tempering*, or both, with the object of decreasing the hardness of the steel and facilitating machining operations.
Softening Temperature. (See PYROMETRIC CONE EQUIVALENT.)
Soisson Rodange Process. A process for the manufacture of high-quality killed basic Bessemer steel in which the steel, after dephosphorization, is poured into another ladle containing the solid components of a basic oxidizing and fluid slag. Blowing for 30 to 40 seconds generates sufficient heat to promote mixing and avoid *skull*. Phosphorus contents are readily lowered and high-quality killed steel is produced with low additional cost. (M. 137.)
Solar Furnace. A method of melting by means of the concentration of the sun's rays. A solar furnace constructed at the California Institute of Technology, was equipped with nineteen single lenses, each 24 in. in diam. used in combination with eighteen smaller plane mirrors and nineteen condensing lenses. These concentrated sunlight within a vacuum chamber, where metals could be vaporized and studied with a spectrograph. (B. 40.)
Solaramic Process. A method for applying a vitreous coating as thin as 0·0005 in. to alloy metals, with the object of obtaining longer life under high temperature conditions, e.g. gas turbine components. The coating materials, consisting of metal oxides and fluxing agents, are blended and smelted and then crushed in a ball mill. To the mill is also added a quantity of water, clay and other binding agents, until a viscous liquid called *slip* is attained. Either spraying or dipping may be used to coat parts, and in most cases a single coating is sufficient. When dry, the coated parts are attached to racks and placed in a furnace, where they are subjected to a firing temperature for a predetermined period, from 10 to 30 minutes, depending on the size and nature of the part.
Solder. A general term for alloys used for joining metals by *soldering*. (See SOFT SOLDERING.)
Solder Embrittlement. Reduction in ductility of a metal or alloy, associated with local penetration by molten solder along grain boundaries. (A. 27.)
Solder Flow Testing. A method for comparing the flow of soft solders on sheet metal, particularly adapted to thin sheets such as tinplate. The method consists essentially of placing a constant-volume pellet of solder on a tinplate disc together with an excess of flux and heating the disc above the melting point of the solder. The extent to which the molten solder spreads on the plate is measured with a planimeter. (S. 92.)
Soldering. Uniting two pieces of metal by means of a third of lower melting point. For satisfactory union, the surfaces to be joined must be metallic, i.e. free from oxide films, and this is assured by using a *flux* which melts at a lower temperature than that of the *solder*. The molten solder and the flux must wet the two surfaces, i.e. make metallic contact with them. For use with soft solder, zinc chloride is a suitable flux. A higher temperature or *hard solder*, which is much stronger, is known as *silver solder*, for which borax is a suitable flux. (See also SOFT SOLDERING.) The practical methods of soldering in common use may be divided into nine processes as follows:
(1) Soldering with the copper bit.
(2) Soldering by torch or flame.
(3) Hot plate soldering.
(4) Induction soldering.
(5) Dip soldering.
(6) Electrode soldering.
(7) Resistance soldering.
(8) Spray soldering.
(9) Supersonic soldering.
Whatever the process used, the solder metal is non-ferrous and has a melting point well below that of the parent metal.
Soldering Acid. A workshop term for *hydrochloric acid*.
Soldiers. Thin pieces of wood used in moulding, to strengthen a body of sand or to hold it in position.
Solex Pneumatic Strip-Measuring Gauge. A gauge for measuring the thickness of strips up to a width of 2¼ in. to an accuracy of 0·002 in. Leakage of air from the orifices in the measuring points is in proportion to the gap between the surface of the material to be measured and the points. Variation of air pressure is indicated on a water column. (E. 47.)
Solid Contraction. The shrinkage occurring in a metal in the solid state as it cools from the freezing point down to room temperature.
Solid Diffusion. (See DIFFUSION.)
Solid Drawing. The forming of shapes from ingots of annular cross-section.
Solid Phase Welding. (See FORGE WELDING.)
Solid Solubility. The extent to which one metal is capable of forming solid solutions with another. This capacity varies considerably; some metals are almost insoluble in each other, whilst

others are mutually soluble in all proportions.

Solid Solution. An alloy in which two or more metals remain dissolved in one another in a homogeneous solid. Under the microscope a solid solution cannot be distinguished from an elemental metal.

Solid Steel. (See KILLED STEEL.)

Solidification Range. (*Crystallization Interval.*) The range of temperature over which freezing occurs, and within which alloys are partly liquid and partly solid. Above this range alloys are completely liquid and below it, completely solid.

Solidification Shrinkage. (See SHRINKAGE.).

Solidoid. (See LIQUIDOID.)

Solidus. A line in a *phase diagram* indicating the temperature at which solidification is completed, or melting begins. (Cf. LIQUIDUS.) (See also IRON-IRON CARBIDE DIAGRAM.)

Soluble Anode. An anode which goes into solution during an electrolytic process.

Solubility. The extent to which a substance will dissolve in a given *solvent* under specified conditions.

Solubility Curve. A line in a constitutional diagram showing the mutual solubility of the two constituents in relation to the temperature. The temperature is plotted vertically whilst the percentage composition is plotted horizontally.

Solute. A substance which is dissolved in another (the *solvent*). Where two mutually soluble metals are concerned the preponderant metal is regarded as the solvent and the other as the solute.

Solution Heat Treatment. A treatment in which an alloy is heated to a suitable temperature and held at this temperature for a sufficient length of time to allow a desired constituent to enter into solid solution, followed by rapid cooling to hold the constituent in solution. The material is then in a supersaturated, unstable state and may subsequently exhibit *age hardening.* (A. 28.)

Solution Potential. The difference in potential of a material and of a reference electrode in a solution. For purposes of comparison standard electrodes and solutions are ordinarily used. (A. 27.)

Solution Pressure. (See OSMOSIS.)

Solution Treatment. (See SOLUTION HEAT TREATMENT.)

Solvent. The medium within which a substance is dissolved. (Cf. SOLUTE.)

Solvus Line. A solid solubility curve in a *phase diagram,* which indicates the limit of solubility of one phase in another at any temperature. (Fig. 7.)

Somatoidal Graphite. The spheroidal form of graphite, in grey iron as it occurs, preferably in hypereutectic iron, under certain conditions of manufacture. (B. 50.)

Sondericker - Ono Fatigue Testing Machine. A rotating beam machine with two equal loads spaced symmetrically along the length of a simple rotating beam loaded by means of dead weights. (A. 35.)

Soniclean. (See DETREX SONICLEAN.)

Sonigage. An ultrasonic testing instrument used primarily for the measurement of the thickness of materials.

Sonim. Solid Non-Metallic Inclusion in Metal.

Soniscope. An inspection instrument, which sends, by electronic means, pulses of high frequency through the material to be tested and measures the time of travel from the transmitter on one face to the receiver on the distant face of the material. This method of inspection is known as *Pulse Testing.* (L. 24.)

Sonizon Ultrasonic Thickness Tester. A portable supersonic instrument for measuring from one side only the thickness of, and detecting flaws in, ferrous and non-ferrous parts. (H. 62.)

Sönnichsen Process. In the manufacture of steel tubes, hot-rolled strip is formed cold into the shape of a tube by means of several pairs of rolls. Electricity is then applied to the open tube by means of several disc-type electrodes which roll right on to the split. The current passes from one electrode to the tube, then along the tube from one electrode to another. The tube is thereby heated gradually and the edges are pressed together and welded between the pressure rolls. After leaving the pressure rolls, the tubing is red hot and can therefore be easily sized down in additional rolls to smaller dimensions. (I. 57.)

Sonntag Rotating Beam Fatigue Machine. In this machine, the specimen functions as a simple beam symmetrically loaded at two points. When the specimen is at rest, fibres above its neutral axis are in tension, and those below this axis, are in compression. As the specimen rotates, the stresses in these fibres are gradually reversed until at the end of one half revolution those originally in tension are in compression, and those originally in compression are in tension. (B. 10.)

Sorbite. A microconstituent of steel consisting of small globules of *cementite* in a matrix of *ferrite.* It is obtained on

tempering hardened steel (*martensite*) at temperatures above about 450° C. or by the decomposition of *austenite*, by cooling too rapidly for the formation of *pearlite* and too slowly to obtain *troostite*. It is harder than pearlite and softer and more ductile than troostite.

Sorbitizing. Increasing the rate of cooling of the surface of steel tyres by means of a spray of air and water, and *tempering* by means of the residual heat. This ensures the presence of tough *sorbite*, instead of *pearlite* (slower cooling) or *martensite* (full quenching).

Sorby, Henry Clifton, F.R.S. (1826–1908.) A pioneer worker on the microstructure of iron and steel. His main achievements were the establishment of a technique for the microscopic examination of iron and steel sections, the development of photomicrography and of macro-etching, the indication of the steel constituent later termed *sorbite* and the virtual establishment of the science of micro-petrography. (E. 4.)

Soret Effect. The difference in concentration in different parts of a solution when these parts are at different temperatures. (P. 34.)

Soro Process. A process of casting and rolling, used to produce solid shapes in sections ranging from ½ in., up to about 4 in. in diameter. A ring is cast in a two-part centrifugal casting metal mould designed so that a riser is cast along its inner periphery. This is removed in the next operation. The ring is then severed and one end is bent outwards so that it can enter a straightening device. The name is derived from the words Schutz, Oerderlin and rotation. (V. 2.)

Sound Vision. A method of non-destructive testing in which, by means of the projection of ultrasonic waves, defects in the interior of materials can be detected and revealed. An accurate image of the defects is obtained and their nature, origin, magnitude, number, position and depth in the material can be deduced therefrom. (D. 31.)

South Kensington Test. (See S. K. Porosity Test.)

Sovereign Gold. Standard 22 carat gold, containing 91·7% gold and 8·3% copper.

Sow. (*a*) The iron cast in the main sand channel into which the stream of molten iron from the blast furnace is led, that from the lateral channels being run into *pigs*. This method has been superseded in modern practice. (*b*) (See Bear). (*c*) A term sometimes used in the non-ferrous foundry for the large basin which receives the whole of the metal required to fill the mould and the feeders.

Sow Block. (*Anvil Cap.*) A block of suitably heat-treated steel, which is placed between the anvil of the hammer and the forging die to minimize the wear of the anvil.

Space Group. A group of points infinitely extended and possessing the same elements of symmetry and the same translations as one of the 230 different arrangements theoretically possible for atoms in crystals. The great number of space groups as compared with *point groups* results from the fact that a different location in space for the same symmetry elements is possible in the space group but not in the point group (A. 27.)

Space Lattice. The dimensional geometric pattern in which the atoms of a metal arrange themselves, and upon which a crystal is built. There are several known lattice configurations but most metals crystallize in one of three types: (1) *face centred cubic*; (2) *body centred cubic*; and (3) *close packed hexagonal*.

Spacer Strip. A metal strip or bar inserted in the root of a joint prepared for a groove weld to serve as a backing and to maintain root opening during welding.

Spalling. (*a*) (*Exfoliation, Flaking.*) The cracking off or flaking of small particles of metal from the surface of a bar or billet during *drop forging*, or from the surface of a roll or case hardened or other very hard surfaced steels. (*b*) A term used to cover a number of different forms of disintegration in refractories. It has been suggested that spalling is the breakdown of the structure of a refractory owing to the irregular mechanical strength of a brick or of a more or less solid mass of brickwork when subjected to thermal shock.

Spangle. The appearance of large zinc crystals on galvanized surfaces.

Spar. An abbreviation for *fluorspar*.

Sparable Ore. A non-metallic tin ore occurring in small granules.

Sparcatron Process. (*Rudorff Process.*) The shaping of metallic parts in a dielectric fluid by a spark discharge. The workpiece and an electrode are immersed in a liquid dielectric, which flows so as to carry away the disintegrated particles resulting from the sparks produced by the discharge of a condenser. The workpiece is connected so as to have positive polarity and the electrode is negative. Thus, the maximum erosion of the workpiece and the minimum erosion of the tool take place. (See also Electromachining.) (E. 60.)

Spark Arrester. (See Cupola.)

Spark Line. A term used in *spectrographic analysis* for a spectral line produced by radiation from atoms in an ionized state.

Spark Machining. (See ELECTRO-MACHINING.)

Spark Re-Ignition. In *argon-arc welding*, the breakdown of the gap to arcing conditions initiated by the high voltage injected by a high-frequency spark oscillator. This implies a lower open-circuit voltage than for self-breakdown, the spark re-igniting the arc as in partial rectification.

Spark Testing. A method of determining the approximate composition of steel by holding a sample on a grinding wheel and producing sparks. An experienced operator can detect differences in the carbon content of steels of ·05% in the range up to ·35% and ·10% in the range from ·35% to ·60%. In certain steels, the effects of alloying elements are also recognizable. (M. 34.)

Sparry Iron. A name, rarely used, for *siderite*.

Spathic Iron Ore. (*Siderite.*) (*Chalybite*). Iron ore consisting essentially of iron carbonate ($FeCO_3$). The iron may be partially replaced by other metals, e.g. calcium, in which case the ore may contain sufficient lime to be self-fluxing. Carbonate ores are *calcined* before charging into the blast furnace.

Spathic Manganese Ore. (See RHODOCROSITE.)

Spatter. The term as used in welding is defined as the unintentional deposits of filler metal on the surface of a parent plate or of a weld, in the form of small globules. (W. 32.)

S.P.B. Steel-Making Practice. (See SHEFFIELD PROCESS.)

Special Addition Agents. (*Intensifiers, Needling Agents.*) The term is applied to a group of ferroalloys containing *boron*. It is claimed that such additions markedly increase the hardenability of the finished steel.

Special Coke Tinplate. Tinplate having usually a specified and heavier weight of coating than *coke quality*.

Specially Improved Patent Steel Wire. (See PATENTED STEEL WIRE.)

Specific Area. (*Specific Surface.*) The total surface area of the particles in one gram of a specific material.

Specific Gravity. (*S.G.*) (*Relative Density.*) The ratio of the mass of a given volume of a substance to the mass of an equal volume of water at a temperature of 4° C.

Specific Heat. The ratio of the *thermal capacity* of a substance to that of water, i.e. the ratio of the quantity of heat required to raise the temperature of a given mass of a substance through a given range to the heat required to raise the temperature of an equal mass of water through the same range.

Specific 0.1% Proof Stress. An empirical figure obtained by dividing the 0·1% proof stress by the density. It is used only for comparison and as a rough indication of the strength/weight ratio of the material.

Specific Pressure. The pressure applied to a powder or sintered compact of unit cross-sectional area.

Specific Resistance. (*Electrical Resistivity, Volume Resistivity.*) The electrical resistance between opposite faces of a unit cube of a given material at a given temperature.

Specific Surface. (See SPECIFIC AREA.)

Specific Tenacity. A value, suggested by *Rosenhain*, representing the ratio of tensile strength to density, and enabling one to obtain a fair comparison of the strength of materials differing widely in density. The specific tenacities of widely different materials are only really comparable, however, if they have similar ductility.

Specific Thermal Resistance. (See THERMAL RESISTIVITY.)

Specific Volume. The volume of unit mass; the reciprocal of *density*.

Specifications. Statements of the requirements, chemical, mechanical or physical, to which a material must conform before it can be accepted for a given purpose. The provision of certain tests and inspection may be stipulated.

Spectrograph. (*a*) A recording form of *spectroscope* for producing photographic or electronically controlled records of spectra. (*b*) In X-ray work, an instrument using an extended surface, i.e. a photographic plate or film, or a fluorescent screen, for receiving the X-ray diffraction pattern.

Spectrographic Analysis. A method of analysis based on the fact that each element when burned in an arc or spark emits characteristic wave-lengths. The greater the amount of the element the more intense the radiation. By measuring the intensity of the light as indicated by the blackness of the recorded lines on a photographic plate or film, precise quantitative analyses are obtainable. More recently, electronic devices enable the direct recording of such intensities without recourse to the use of film. The instrument, known as a *Direct Reading Spectrograph*, enables very rapid analysis of metals to be obtained. (S. 61.)

Spectrometer. (*a*) An instrument for obtaining and measuring spectra. (*b*) An instrument using a movable measuring

device for exploring the X-ray diffraction pattern.

Spectroscope. An instrument used to disperse light, permitting analysis of a complex beam according to wavelength. (See SPECTROGRAPH, SPECTROGRAPHIC ANALYSIS.)

Spectrum. The dispersed beam of light obtained in a spectroscope. With white light this produces the "rainbow" series of colours resulting from the breaking up of the white light into its components. In analysis by emission spectrography, the spectrum takes the form of a series of characteristic lines lying throughout the visible and ultra-violet regions.

Speculum Electroplate. A coating which consists of about 40% tin and 60% copper. Although not entirely tarnish resistant, for many purposes it affords a very satisfactory finish.

Speedicase. A liquid case hardening medium suitable for the production of a case of moderate thickness, the maximum penetration being 0·05 in. (W. 46.)

Speiss. Metallic arsenides and antimonides resulting from smelting metal ores, such as those of cobalt.

Spek-Chek. (See DYE PENETRANT INSPECTION METHOD.)

Spekker Photoelectric Absorptiometer. An instrument used in *colorimetric analysis*. It consists essentially of a light source, two photoelectric cells, and a galvanometer. A beam of light passes through a solution of the sample contained in a glass cell, and then falls on another lens which forms an image of the lamp filament on the indicating photocell. A calibrated aperture enables the intensity of the light falling on the photocell to be varied by known amounts. Light from the lamp also passes through a second filter, and an iris diaphragm, into a compensating photocell. The two photocells are connected in opposition across a galvanometer so that, when the currents given by them are equal, the galvanometer shows zero deflection.

Spellerizing. (*Roll Knobbling.*) A process in which a heated *bloom* is passed alternately through rolls, having specially designed projections on their surfaces, and through smooth rolls, in such a manner as to produce a uniform surface finish.

Spelly Wire. A defect in wire due to *segregation*, and liable to cause fracture in drawing.

Spelter. A term formerly applied to all grades of commercial zinc, but now usually applied only to grades of lower purity (under 99·6% zinc). *Hard spelter* consists of an alloy of zinc and iron formed in the galvanizing bath by the reduction of the iron salts on the surface of the steel being galvanized.

Spelter Solder. (*Brazing Spelter.*) A brazing medium consisting of copper and zinc. British Standards specifications cover two grades, viz., copper 53% to 55%, and 49% to 51%, the remainder in each grade being mainly zinc with some impurities.

Sperry Process. An electrolytic process for the manufacture of white lead.

Sperry Supersonic Reflectoscope. An instrument for detecting flaws in billets and blooms up to 20 in. square or, for example, for the detection of internal defects in rails. The presence and position of defects are determined by measuring the difference in the times at which reflections of waves of supersonic frequency transmitted from one side of the billet are received from the opposite surface and from the defect. (R. 50.)

Sp. Gr. Abbreviation for *specific gravity*.

Spheroidal Graphite Cast Iron. (See CAST IRON.)

Spheroidite. *Cementite* which has taken the form of rounded spheroids. It may be formed by heating *hypereutectoid* steel for a prolonged period at a temperature just below the *eutectoid* transformation. (See DIVORCED PEARLITE.)

Spheroidize Annealing. (See SPHEROIDIZING.)

Spheroidized Cementite. (See DIVORCED PEARLITE.)

Spheroidizing. (*Spheroidize Annealing.*) The prolonged heating of steel, at a selected temperature within or near the *transformation range*, with subsequent slow cooling, in order to obtain the carbide in a globular form. The process is usually applied to high carbon steels to obtain improved machinability, to facilitate subsequent *cold working* or to obtain a desired structure for subsequent *heat treatment*. (S. 114.)

Spiegeleisen. (See MANGANESE.)

Spigot. The plain end of a length of pipe or tube which is fitted into the enlarged or *socket* end of the next length, the joint being made tight, to prevent leakage, by *caulking*.

Spiking. (*Blocking, Stopping.*) A term used in the U.S.A. for the operation of adding ferro-manganese, silico-manganese, or other deoxidizing agent, to an open hearth bath for the immediate stoppage of all oxidizing reactions.

Spill. (See SLIVER.)

Spilliness. Flaking of the surface of wire due to a defect in the hot rolling of the wire rod. Also applied to larger semi-finished products, such as slabs or bars, but here more usually termed *shelliness*, or *shell*. (See also SPLASH.)

Spin Dimpling. The forming of conical recesses or dimples in sheet material for the reception, for example, of the heads of screws or rivets.

Spin Drawing. A method used for shapes which cannot be drawn completely to final contour without encountering wrinkles, buckles, or fractures. The metal may be drawn to the point where such conditions are about to appear and then given their final shape by spinning. (I. 39.)

Spin Hardening. A method in which the part is rotated for many revolutions in the flame of a stationary blowpipe. (S. 43.)

Spindel Machine. A *wear* testing machine in which the specimen is pressed against a rotating disc; it is suggested that the disc should rotate at a peripheral speed of 25 m. per min. under a pressure of 5 kg. for soft and 10 kg. for hard materials, while the abrasion length (the distance travelled by a point on the circumference of the disc during a test) is varied. The surface of the segment ground away is used as the measure of the wear. (E. 8.)

Spindle. A rod or axis which revolves or upon which a thing revolves, e.g. in a *foundry*, the rod or centre on which a *sweep* is revolved; in a *rolling mill*, the shaft or coupling between the pinions and the rolls permitting power to be transferred to the rolls.

Spindle Seat. A socket in which the *spindle* revolves.

Spinel. The name applied to a group of minerals of general formula XO, Y_2O_3 or XY_2O_4 where X may be a divalent metal such as magnesium, nickel, iron, cadmium, copper, manganese or zinc and Y a trivalent metal such as aluminium, iron, chromium, gallium, indium or vanadium. Some other minerals, particularly those of general formula X_2YO_4 may have the same structure as spinels. Common spinel approximates to $MgAl_2O_4$ but extensive substitution may occur with the univalent and trivalent metal ions. Spinels belong to the isometric system, have imperfect cleavage, and often exhibit simple or complex twinning on octahedral faces. Many of the spinels form natural refractories and are used extensively as such, whilst most spinels can be made artificially from oxides. They easily form mixed crystals, e.g. in chrome ores, and may exhibit the phenomenon known as *bursting expansion* when heated in contact with magnetite (Fe_3O_4). Bursting expansion is an important factor affecting the service life of refractories in some types of steel melting furnaces.

Spinner. (*a*) A rotating member in a wire straightening machine containing the dies which straighten the wire. (*b*) Also the term sometimes used for the rotating mould in *centrifugal casting*.

Spinning. (*a*) The cold forming of a flat metal blank into a shallow vessel in which the blank is pressed against a rotating chuck or pattern of the shape which the blank is intended to take. Both the chuck and the blank are caused to revolve by means of a lathe. The blank is then forced over the chuck by tools, either mechanically or by hand. Intermediate annealing may be necessary as work hardening progresses. (*b*) (See REELING).

Spinning Chuck. The form which shapes the metal in the *spinning* operation.

Spiral Contractometer. An instrument for measuring stress in electrodeposited coatings. A flat strip is wound to form a helix and is plated on one side only; the stress in the deposit causes the helix to wind more tightly or to unwind, depending on whether the stress is compressive or tensile; this movement is indicated by a pointer connected to the helix through suitable gearing. (B. 85.)

Spiral Test. A method of interpreting the fluidity of an alloy. The test consists of pouring molten metal into a mould which carries a long and narrow channel along which the metal runs. The length of such a casting produced under standardized conditions is taken as the *fluidity* index of the alloy. (Y. 3.)

Spirits of Alum. *Sulphuric acid.*

Spirits of Copper. Acetic acid obtained from copper acetate.

Spirits of Hartshorn. An aqueous solution of *ammonia*, the name being derived from the old method of obtaining ammonia by heating the hoofs and horns of animals.

Spirits of Nitre. (*a*) Nitric acid. (*b*) A solution of ethyl nitrite in alcohol.

Spirits of Salt. Hydrochloric acid.

Spirits of Sulphur. Sulphurous acid.

Spirits of Tin. Stannic chloride.

Spirits of Verdigris. Acetic acid.

Spirits of Vinegar. Dilute acetic acid.

Spirits of Vitriol. Sulphuric acid.

Spirits of Wine. Ethyl alcohol.

Spirits of Wood. Methyl alcohol.

Splash. (*Shell.*) (*a*) A roughened area on the side of an ingot. The defect is due to metal, splashed during *teeming*, which has solidified and adhered to the corresponding area on the mould wall. (*b*) The defect on slab or billet caused by the elongation or partial detaching of such material. (See also SPILLINESS.)

Split. A defect in wire consisting of a longitudinal division which may be of

considerable length and which opens on bending.

Split Die. (See SEGMENT DIE.)

Split Pattern. A *pattern* made in two or more parts.

Split Pattern Squeezer. A squeezer type *moulding machine*, adapted to moulding *split patterns*.

Split Thermocouples. A method for continuous measurement of liquid steel temperatures in which the *thermocouple* elements are led through the furnace lining into the metal at some distance apart, the molten charge thus completing the circuit and acting as the hot junction. (S. 35.)

Split Transformation. The appearance of two *arrests* on cooling.

Splits. (See SCONES.)

Spodumene. (*Hiddenite.*) A mineral, lithium aluminium silicate, generally containing a small amount of sodium. It is a source of *lithium*, and it is claimed that the addition of this mineral in either the basic or acid steelmaking process results in the removal of about 55% of the sulphur content of the steel and about 45% of that in the slag, with a marked increase in fluidity of both steel and slag. (M. 168.)

Spoiling. The deterioration in coercive force caused by holding a 6% tungsten magnet steel at a temperature of 950° to 1000° C. prior to hardening. It is suggested that this spoiling is caused by the formation of a separate carbide phase which reduces the amount of tungsten and carbon available to promote hardening.

Sponge Iron. Finely divided iron, obtained by the direct, low temperature reduction of iron ores. In this state, iron oxidizes readily.

Sponginess. (See POROSITY.)

Spongy. A porous condition in powder particles usually observed in reduced oxides. (G. 30.)

Spongy Castings. A term applied to castings in which the iron is very open grained, or which contains surface or *subcutaneous blowholes*.

Spongy Top. (See CAULIFLOWER TOP.)

Spontaneous Annealing. (See SELF ANNEALING.)

Spool Roll. A roll, on a *roll table*, which is provided with discs to prevent the lateral movement of the rolled product and to carry it away from the mill.

Spoon. (See SAMPLING SPOON.)

Spoon Sample. (*Bath Sample.*) A sample of steel taken from the molten bath, by means of a *spoon*. (See SAMPLING SPOON.)

Spoon Slicker. A tool with a spoon-shaped end used for smoothing the *mould*.

Spoon Tool. A moulding tool for use on rounded surfaces or for cutting circular depressions in the *mould*. (P. 9.)

Spotchek. (See DYE PENETRANT INSPECTION.)

Spot-Spark Method. A micro-spectrographic method for the quantitative analysis of steel segregates. (B. 16.)

Spot Welding. A *resistance welding* process of joining two or more overlapping sheets by local fusion of a small area or spot. Two dome pointed, copper alloy electrodes contact either side of the overlapped sheets, under known loads produced by spring or air pressure. A relatively large, low voltage electric current is passed through the electrodes and the work for a short interval of time. A small volume of material, centred on the *faying* (contact) *surfaces* of overlapped portion, but not extending to the outside surfaces, is fused by the current and forged by the pressure. (W. 61.)

Spout Pouring. (See TROUGH CASTING.)

S.P.R. Simplified Practice Recommendation.

Sprabond Process. A method for the preparation of surfaces for metallizing, in which a special alloy is sprayed on to a smooth surface, giving good adherence and acting as an undercoat for subsequent layers. (M. 73.)

Spray-Gun Bonderizing. A *bonderizing* development utilizing a cold processing solution which is applied to sheet metal by means of an ordinary paint-type spray gun. (S. 51.)

Spray Quenching. A mode of quenching in which a spray of water is directed upon material just removed from the furnace. It is sometimes used after solution heat treating, and is claimed to be more effective than *fog quenching*. Both methods are designed to reduce the risk of distortion which may occur in normal quenching by immersion in a tank of water or brine.

Sprayweld Process. (*Colmonoy Sprayweld Process.*) A *hard facing* process in which the parts are first sprayed with a proprietary hard facing powder, then heated to fusing temperature either by means of an oxy-acetylene torch or by heating in a controlled atmosphere furnace at approximately the same temperature, and allowed to cool under controlled conditions. The hard surface is thus fused or welded to the base metal. (H. 67.)

Spread. The amount by which material intended for *sheet* or *strip* increases in width as a result of rolling. It is usually expressed as a fraction of the original width.

Spreaders. Pieces provided on *patterns* to counteract the tendency to distortion in certain types of castings. The portions of the mould left by these pieces have to be filled in before the job is cast. This can be accompanied by *stopping off*, that is, filling the mould cavity with loose sand or dropping a core in position. (F. 36.)

Spreading. The ability of a liquid to form a persistent and continuous liquid-to-solid interface solely by surface activity over the plane surfaces. (L. 29.)

Sprengel Tube. (See PYKNOMETER.)

Sprigging. Reinforcing the face of moulds by inserting sprigs or nails into the sand to just below the face. The impressions so made are then smoothed over before casting.

Sprills. In *powder metallurgy*, metal particles of cylindrical form with height not much greater than diameter.

Spring Back. A characteristic of certain hard metals and alloys of recovering part of the deformation resulting from a blow or from formation in a die.

Spring Draw Nail. A tool for drawing patterns, especially gear patterns, by gripping the inside of the hole in the hub. (P. 1.)

Spring Steels. Essentially hard steels with high elastic limits. Certain springs are made from plain carbon steel with 0·5% to 1·2% carbon, but more reliable properties are provided by silico-manganese, and chromium-vanadium steels. The silico-manganese steels are usually employed for the production of laminated springs and torsion bars for automobiles and the chromium-vanadium steels are more generally used for coil springs for aero-engine valves. Typical spring steels are covered by B.S.970:1955, En42 to En50.

Springing Test. A test for cutlery which is applied by inserting the tip of the knife blade under a metal clip fixed on the periphery of a wooden block, and bending the knife round the periphery until the blade throughout its length is in contact with the block. It is required that the blade shall withstand this test without fracture or permanent set. The diameter of the block varies according to the type of cutlery being tested. (G. 39.)

Sprue. (*a*) In casting, the channels leading from the *gate* to the mould. (*b*) The metal which solidifies in these channels after the casting has cooled. (*c*) In forging, the portion of the die which is machined out to permit a connection between multiple impressions or between the impression and the forging bar.

Sprue Button. A *print* attached to the upper part of a mould. It forms an impression on the *cope* and thus indicates the correct position for the *sprue*.

Sprue Cutter. (*a*) A piece of metal used to cut channels in the *joint* to conduct molten metal from the pouring gate to the *mould*. (*b*) A brass tube used to cut the pouring gates in the *copes* of machine made moulds. (P. 1.)

Sprueing. The removal of *gates* from the solidified casting.

Spun Cast Pipes. Cast iron pipes made by *centrifugal casting*. Molten iron produced in a cupola is poured from a transfer ladle into the casting machine ladle which is hydraulically tilted so as to maintain a constant pouring rate. A water cooling box surrounding the spinning mould travels slowly down it as the metal is poured. The combination of the axial and circumferential movements causes a continuous spiral of molten iron to be deposited on the inner surface of the mould where it rapidly solidifies owing to the heat extracted by the cooling box. Subsequent operations include dressing, dipping, testing, weighing, and if required, lining with cement. (See also DE LAVAUD PROCESS.) (D. 14.)

Spun Pipes. (See DE LAVAUD PROCESS.)

Spun Refined Irons. Cast irons made by spinning the molten iron in a basin-shaped vessel, thus expelling slag, oxides or other inclusions by centrifugal force.

Squaring Shear. A shear for trimming sheets of tinplate so as to true up the edges, bring to close tolerances in dimensions and ensure that the corners conform to 90°.

Squeeze Period. The time interval in a resistance welding process, between the initial application of pressure and the application of welding current.

Squeezer. A machine, now obsolete, for solidifying the bloom produced in the *puddling process*. Squeezers consisted of various forms. The *crocodile* had a fixed bottom jaw and a movable upper jaw, the descending top jaw pressing the bloom and squeezing out the liquid slag.

Squeezing. (*a*) Forming a bloom or billet by pressure instead of by hammer blows. (*b*) A term applied in the U.S.A. to include all operations in which the material is worked under compression. These include *impact extrusion*, *swaging*, *cold forging*, *cold rolling*, *sizing*, *coining* and *stamping*.

Squeezing Machine. A machine by means of which sand is pressed into the moulding box, thus eliminating hand ramming.

Squirt Welding. (See SUBMERGED ARC WELDING.)

Sr. Chemical symbol for *strontium.*

S.A.S.M.U.T.A. Sheet and Strip Metal Users Technical Association.

S.S. Pendulum Hardness Tester. A simplified model of the standard *Herbert Pendulum Hardness Tester.* It consists of an arched weight of 4 kilos resting on a steel ball of 1 mm. diam., held in a chuck, so that the constants of the instrument and the readings obtained are identical with the standard Herbert Pendulum Hardness Tester. (E. 19.)

S.T.A. Specifications. Specifications issued by the British Standards Institution for the Ministry of Supply.

Stabilization. (*a*) The retarding or prevention of a particular reaction by the addition of a *stabilizer,* or negative catalyst. (*b*) A stabilizing heat treatment, to relieve internal stresses. (See STRESS RELIEVING.) (*c*) A treatment of a magnetic material designed to increase the permanency of its magnetic properties or condition.

Stabilizers. Elements added to austenitic *stainless steels,* of the type containing 15% to 20% of chromium and 12% to 8% of nickel, for the purpose of forming a stable carbide with the carbon, thus preventing any tendency to *intercrystalline corrosion* or *weld decay.* The stabilizers in most common use are titanium and niobium.

Stabilizing Anneal. A treatment applied to austenitic stainless steels containing titanium or niobium. This treatment consists of heating to a temperature below that of a full anneal in order to precipitate the maximum amount of carbon as titanium carbide or niobium carbide. This eliminates precipitation at lower temperatures, which might reduce the resistance of the steel to corrosion. (A. 27.)

Stabilizing Treatment. A thermal treatment designed to precipitate material from solid solution, in order to improve the workability, to decrease the tendency of certain alloys to *age harden* at room temperature, or to obtain dimensional stability under service at slightly elevated temperatures, or to prevent distortion on machining. (A. 27.)

Stable Equilibrium. (See EQUILIBRIUM.)

Stack. (*a*) The part of the *cupola* extending from the top of the *melting zone* to the level of the *charging door.* (*b*) (See BLAST FURNACE).

Stack Cutting. Oxygen cutting of stacked metal plates arranged so that all the plates are severed by a single cut.

Stack Moulding Process. A foundry technique which consists of using half moulds stacked on top of each other and fed from a common downgate. It is especially applicable in cases where the flat top of one mould can be used as the bottom of the mould directly above it. (B. 110.)

Staff. A *rabble* used in *puddling.*

Staffordshire Iron. High-grade wrought iron originally made in Staffordshire from local iron ore. The term as now used, has no special significance without further qualification.

Staffordshire Marked Bars. Well-known qualities of *Staffordshire iron* made to the maker's guarantee. (See also QUALITIES.)

Staflux. A material made by sintering together lumps of limestone and certain kinds of iron oxide, such as iron ore or mill scale, at a temperature of 1450° C. in a rotary furnace. Though fusion does not occur, the iron oxide penetrates the limestone completely and rapidly, and forms dicalcium ferrite. (S. 72.)

Stagger Weld. A *cold-welding* process in which a number of dots or short straight-line welds are slightly staggered so that they lie along two or more parallel lines. The welds are formed with a special tool applied to the thin sheet side of the work. (D. 46.)

Stainless Clad Steels. (See CLADDING.)

Stainless Iron. (See STAINLESS STEELS.)

Stainless Steels. (*Corrosion-Resistant Steels.*) These include three groups of steels: (1) *Ferritic,* containing less than 0·10% carbon and from 11% to 30% chromium. The steels of this group cannot be appreciably hardened by heat treatment and those containing 12% to 14% chromium are known commercially as *stainless irons*; (2) *Martensitic,* containing more than 0·10% carbon and 11% to 20% chromium and in which nickel may be present in amounts up to 3%. These steels can be hardened by quenching and include the cutlery, e.g. 0·30% carbon and 13% chromium, and engineering types, e.g. 0·22% carbon and 13% chromium as well as steels containing 18% chromium and 2% nickel made to British Standard S. 80. (3) *Austenitic,* in which the minimum chromium and nickel contents are 11% and 8% respectively, whilst the total chromium and nickel content must be at least 23%. This group includes the well-known 18/8 types and the 12/12 deep-drawing quality. Unless the carbon content is very low (about 0·03%) the austenitic stainless steels are susceptible to *intercrystalline corrosion* attack if, as a result of welding or hot working, they are heated within, or allowed to cool slowly through the temperature range 400° to 900° C. This

defect which, when occurring in welded structures, is alternatively known as *weld decay*, may be obviated by additions to the steel of *stabilizers*, the most important of which are titanium, which is added in amounts of at least 4 times the carbon content, and niobium which is added in amounts of at least 8 times the carbon content. Molybdenum may be added to the austenitic stainless steels if increased corrosion resistance is required in certain reagents such as sulphuric, acetic and phosphoric acids. Specifications covering the various types of stainless steels are given in B.S. 970: 1955.

Stainless Steel Powder. A method has been evolved of producing low carbon stainless steel powder of the 18/8 variety. Graded powder is thoroughly mixed with a porosity forming agent which volatilizes during the initial sintering operation. Pressing in dies results in a uniform compact of controlled porosity. The green pressings, usually in sheet form, are initially sintered, and finally resintered, at a high temperature in a reducing atmosphere of dry hydrogen. This procedure promotes the diffusion-welding of mutually placed angular particles thus ensuring porous-metal compacts of high strength and ductility. The material thus produced may be used, for example, in the manufacture of filters. (I. 75.)

Stamping. (*a*) A product made by the sudden impact of a hammer on metal in a die, either in the cold or red-hot state, for drop stampings. (See DROP FORGINGS.) (*b*) A process used to cut lines of letters, figures and decorations on smooth metal surfaces. The impact of a punch with comparatively sharp projecting outlines impresses the characters into the surface of the metal.

Stand. (See ROLLING MILLS.)

Standard Calorie. The 4° calorie. (See CALORIE.)

Standard Electrode Potential. (See STANDARD POTENTIAL.)

Standard Gold. A legally adopted alloy for gold coinage. In the United Kingdom it contains 8·33% copper, and in the U.S.A., 10% copper.

Standard Potential. (*Standard Electrode Potential.*) Standard potential of an electrolytic reaction is the theoretical reversible potential for a system in which the products and reactants are at unit activity. Conventionally the standard potential of an $H \rightleftharpoons H^+$ electron reaction is taken as zero.

Standard Silver. (See SILVER.)

Standard Solution. A solution of known strength used in *volumetric analysis*.

Standard Temperature and Pressure. (*S.T.P.*) A temperature of 0° C. with a pressure of 760 mm. of mercury.

Stanfield Hardness Tester. An instrument designed for workshop use on sheet metal and cutlery. It took the form of a pair of pliers, employing a ball indenter, the load being controlled by a spring arrangement. The indentation was measured by a medium-power microscope. Its scope was limited, e.g. its operating load was 180 kg. which did not permit testing very thin sheet material, and it has been superseded by the *Firth Hardometer*. (W. 68.)

Stannate. A salt of *tin*.

Stanniferous. Containing *tin*.

Stannizing. A process for coating iron and other metals with tin by exposing them to stannous chloride vapour in an atmosphere of hydrogen.

Stannometer. A magnetic testing device for determining the thickness of metallic coatings on iron. (R. 23.)

Stannum. The Latin name for tin, hence the chemical symbol *Sn*.

Stanton and Bairstow's Fatigue Testing Machine. This machine is similar to the *Reynolds and Smith* alternating stress testing machine, but the oscillations are produced by four cranks operating horizontally, the specimens, therefore, being free from any stresses due to the dead weight of the reciprocating masses. The machine was designed for speeds up to 2000 r.p.m., but most tests are carried out at a constant speed of 800 r.p.m. (G. 36.)

Stanton and Bairstow's Repeated Direct Impact Machine. In this machine, the specimen is locked in two concentric hard steel sleeves. An adjustable tup falling on the sleeves produces tensile impact stress. The specimen and sleeves are then rotated through 180° and the tup released again to produce compressive impact stress on the test piece. The striking energy of the tup and the number of blows required to fracture the specimen are recorded. (G. 36.)

Stanton and Batson Fatigue Testing Machine. A modification of the Wöhler machine for applying either, or a combination of, reversed torsional and reversed plane bending stresses. The speed of the machine is 2000 r.p.m. (G. 36.)

Stanton Fatigue Testing Machine. A machine for the application of combined alternating bending and abrasion, for reproducing the actions to which railway lines are subjected. The specimen is placed between three, symmetrically spaced and equally loaded rollers, the upper roller rotating at 800 r.p.m. and the two lower ones being

driven by the frictional resistances between themselves and the specimen. The outer surface of the ring is thus subjected to alternate bending stress at the rate of three complete cycles per revolution, which can be calculated from the dimensions of the specimen and the magnitude of the applied load. (G. 36.)

Starck Effect. The separation of spectral lines into their components by the action of a strong electric field.

Starting Sheet. A thin sheet of metal used as cathode in electrolytic refining. (A. 27).

Stassano Direct Reduction Process. A method using a Stassano electric furnace for the direct reduction of iron and steel from ore. The furnace was similar to a blast furnace, the tuyeres being replaced by carbon electrodes, at a slight angle to the horizontal, allowing an arc to be formed in the body of the charge. The furnace was charged through a hopper at the head of the shaft, whilst the molten iron collected below the electrodes. The charge consisted of crushed ore, mixed with charcoal and flux, in the form of briquettes. The process worked satisfactorily, but the economic costs were too high.

Stassano Furnace. An electric furnace of the direct arc type, in which the heat is radiated from an arc which is not in contact with the charge. It consists essentially of a refractory-lined chamber, into which are introduced two, or in some cases, three carbons. The carbons are in the same plane and are slightly inclined from the horizontal. The bath of metal is immediately below the carbons and derives its heat from the arc which is formed between the tips of the electrodes. (H. 6.)

Stathmograph. An apparatus which records automatically, in the form of a graph, the loss of weight during the whole reduction of iron ores. (D. 36.)

Static Crack Strength. The force required to fracture a specimen having a fatigue crack or filed notch.

Static Electricity. Non-flowing electricity, usually generated by friction.

Static Electrode Force. (See ELECTRODE FORCE.)

Static Load. Load applied slowly and steadily, in contradistinction to *impact* or *shock*.

Static Water Drop. A corrosion test whereby one or more drops of water are maintained on the surface of a coated panel and observed at specified intervals.

Statics. That branch of physics concerned with the equilibrium of forces acting upon bodies.

Stationery Office. (See HER MAJESTY'S STATIONERY OFFICE.)

Statobloc Wire-Drawing Machine. The essential feature of the machine is that the die is mounted on a revolving drum, and traverses a circular path round a stationary block on which each newly formed coil of wire pushes the preceding coils on to a collecting holder which can be removed when full and a new holder substituted without stopping the machine. (W. 64a.)

Statutory Instruments. (*S.I.*) A series of orders issued by Government departments and published by *Her Majesty's Stationery Office*.

S.T. Curve. Specific heat/temperature curve.

Stead, John Edward, D.Sc., F.R.S. (1851–1923.) One of the first metallurgists to realize the importance of *Sorby's* investigations on the microstructure of iron and steel. Dr. Stead's contributions to the knowledge of the crystallization phenomena in iron and steel were such that he came to be regarded as one of the world's chief authorities on this subject. He made important improvements in the technique of microscopic metallography and his method of heat tinting specimens by oxidation became an accepted method in the metallographic examination of steel.

Stead's Brittleness. A type of brittleness caused by enlarged grain size on annealing after a critical amount of *cold work*. It is usually found in low carbon steels and is shown by the decrease in the notch impact value.

Stead's Reagent. An etching reagent, used in the metallographic examination of steels, containing 100 ml. methyl alcohol, 18 ml. water, 2 ml. concentrated hydrochloric acid, 1 g. copper chloride ($CuCl_2.2H_2O$), 4 g. magnesium chloride ($MgCl_2.6H_2O$).

Steadite. A constituent found in all irons containing more than 0·1% phosphorus. In grey cast irons it consists of a binary eutectic of ferrite, with phosphorus in solution, and iron phosphide, Fe_3P. It contains 10% phosphorus and 90% iron. In white cast iron it consists of a ternary eutectic comprising ferrite with phosphorus in solution, cementite (Fe_3C) and iron phosphide (Fe_3P). Steadite was so named by Sauveur, as it was first described by *Stead*. It has the lowest melting point of all the constituents of cast iron and is therefore found at the grain boundaries. Under the microscope it appears as a white area containing black specks.

Steam Blueing. (See BLUEING.)

Steam-Homo. A technique of using a steam atmosphere in heat treating furnaces. Both ferrous and non-ferrous materials can be so treated. As regards steels, the surface reacts with the steam to form a thin layer (0·0002 in.) of magnetic iron oxide which, it is claimed, prevents the formation of excessive scale during heat treatment. (See BLUEING.) (P. 7.)

Steam Table. A table of steam properties expressed as functions of the pressure or temperature.

Steatite. (See TALC.)

Steckel Mill. A mill for the cold rolling of strip. It consists of a 4-high stand, in which the work rolls are not driven, the strip being pulled through it against a back tension. The work passes from the loaded power reel via the first cooling drum to the work rolls and thence over the second cooling drum to the empty power reel. When the strip has been transferred from one drum to the other the mill is reversed and reduction proceeds in the opposite direction. The strip produced in this type of mill is of very high quality, accuracy of gauge, and excellency of finish. (M. 167.)

Steel. A malleable alloy of iron and carbon, the carbon content being usually less than 1·7%. It is produced in the fluid condition, either by the *crucible*, *Bessemer*, *open hearth*, or *electric furnace*. Such steel is practically free from *slag*. *Shear steel* is an exception to this definition. (See also CARBON STEEL, CAST STEEL, and ALLOY STEEL.)

Steel Moulders' Paint. *Compo* mixed very thin and applied with a stiff brush to the face of a *mould*.

Steel Plate Thickness Meter. A portable instrument for measurement of the thickness of steel plates requiring access to one side of the plate only. It employs a magnetic method. The measuring head of the instrument consists essentially of a pot-shaped electromagnet with provision for indication of the total magnetic flux in the main magnet circuit. On application of the electro-magnet to the plate under examination, saturation flux density is produced in the body of the plate and the total flux indicated is directly related to the plate thickness. (C. 13.)

Steel Sorter. An instrument for the rapid identification of steels. It depends on the principle that the magnetic characteristics of a steel vary with its composition.

Steel Test Hardness Tester. This instrument can be operated at three speeds and is capable of making 1200 to 2700 tests per hour. The readings appear on a standard 100-division dial, in all scales. Operation is almost entirely automatic, the only manual operations being the initial setting of one specimen in each batch run and the feeding of the specimens. The travel of the penetrator is fully automatic, and is synchronized with two flasher lights located directly below the indicating dial. The penetrator is encased in a housing which shields it from all possible damage. The nose-piece of the housing is designed with a guard so that the smallest parts may be tested without endangering the fingers. (M. 99.)

Steeling. A term used in the *crucible process*, for the operation of charging the raw material into the *pots* by means of an iron funnel known as the *charger*.

Steelmaking. The production of steel from pig iron with or without steel scrap, together with other additions, according to the type of steel required. By far the greatest tonnage is made in the *basic open hearth*, the *acid open hearth* producing only about a tenth of the amount. In the United Kingdom the use of the Bessemer process has become very limited, but on the Continent of Europe the output of Bessemer steel remains considerable. The tonnages produced in *electric arc* and *high frequency induction furnaces* are very small as compared with that of the open hearth, but since the highest quality high alloy steels are produced in these furnaces, their value is of far greater importance than the tonnage figures would suggest. The *crucible process* has been almost entirely, but not quite, superseded by high frequency induction melting. The *cementation process* is now obsolete.

Steeloscope. An instrument, by means of which the metallic elements in steel can be readily estimated from the arc spectrum of the sample. (A. 59.)

Steelyard. The Roman balance, an instrument for weighing, consisting of a lever with unequal arms, in using which a single weight or counterpoise is employed, being moved along a graduated beam.

Stefan Boltzman Law. The energy radiated in unit time by a black body is given as $E = K(T^4 - T_0^4)$, where T is the absolute temperature of the body, T_0 the absolute temperature of the surroundings, and K a constant.

Steigerite. ($Al_2V_2O_8.6\frac{1}{2}H_2O$.) A vanadium ore.

Stein Suspended Furnace Roof. A system of roof construction in which each alternate block is supported by a pin passing through the centre of the

block towards its upper extremity. (I. 45.)

Steinmetz Coefficient. A measure of the loss of energy per unit volume per cycle due to magnetic hysteresis. It is approximately proportional to B^n where n is about 1·6.

Step. A term used in *die forging* for a change in the plane of a *die* face.

Step Gauge. (*Film Thickness Comparator.*) This consists of a film of barium stearate deposited in a series of successive monomolecular layers upon a plate of special glass. Each layer has a thickness of 0·1 micro-in., and the successive layers are deposited in such a way as to build a series of steps which differ in thickness by one micro-in. When the step gauge is illuminated by white light, each step reflects a colour, which is determined by the thickness of the step. The step gauge serves as a standard of comparison with other films and can also be used indirectly to measure vapour pressures and temper colours on metals. The measurement is simple and direct, the colour of the layer to be measured being matched with that of one of the steps of the gauge. The range of the new gauge extends from 2 to 16 micro-in. (E. 70.)

Step Grating. A series of openings in a vertical plane.

Step Quenching. (See MARTEMPERING.)

Step Structure. (See ELECTROLYTIC OXALIC ACID ETCH.)

Step Wedge Penetrameter. (See PENETRAMETERS.)

Step Welding. A process, which is particularly suitable for alloyed tool steels that are prone to crack on welding. There are two modifications. In the first, the material to be welded is heated to its *austenitizing* temperature, held there, and then cooled to a temperature at which the austenite transforms only very sluggishly to the pearlitic or intermediate structure; it is welded at that temperature, with a welding rod, the hardening temperature of which coincides with the welding temperature. The whole is then allowed to cool naturally to room temperature, and annealed at low temperatures. When the austenite transformation is not sufficiently sluggish, the second procedure is employed. Here the material is heated as before, but cooled to a temperature at which the austenitic state of the welding rod material is more stable, and welding carried out. In this case, the body of the material remains soft. In both cases the welds are free from cracking. (N. 17.)

Stepback Sequence. (See BACKSTEP SEQUENCE.)

Stepped Extrusion. A type of metal extrusion in which the size of the contour changes abruptly in order to decrease the amount of machining necessary to make tapered members. (A. 27.)

Stereochemistry. (*Stereometry.*) The study of the spatial arrangements of atoms in a molecule.

Stereogoniometer. A device for measuring the orientation of crystals in coarse-grained polycrystalline metals. By means of a link mechanism, the orientations are instantaneously transferred to a plotting table to give their correct positions on a stereographic projection.

Stereogram. A model diagram giving a representation of data in a three-dimensional form.

Stereographic Projection. A projection in which each plane of a crystal is represented by the point at which a perpendicular, allowed to fall upon it from a fixed point, meets a sphere, centred at the fixed point. These representative points on the sphere are represented in turn by the points at which lines drawn to them from the pole of a great circle of the sphere meet the diametral plane through the great circle.

Stereoisomerism. The existence of different substances whose molecules possess an identical structure but a different spatial arrangement of their atoms.

Stereometer. An apparatus for determining the specific gravity of powders or porous materials.

Stereometry. (See STEREOCHEMISTRY.)

Stereoptics. The theory and practice of stereoscopy, e.g. an auto-stereoscopic photograph is one giving a three-dimensional or solid effect, without the use of a viewing device by the observer.

Stereo-X-Ray Apparatus. An apparatus in which a stereoscopic pair of X-ray generators is actuated respectively by the positive and negative half-cycles of a 50-cycle A.C. supply. The screen is viewed through eyepieces in which the left and right eyes are alternatively obscured by shutters controlled magnetically by the same 50-cycle supply. Persistence of vision gives a stereoscopic effect. (L. 57.)

Sterling, Robert. (1790–1878.) A Scottish scientist, who patented the regenerative principle (1847).

Sterling Silver. (See SILVER.)

Stethoscope Test. A test, which has been sometimes applied to welds to detect unsoundness. It is applied by listening with a stethoscope to the note emitted when the weld is tapped with a hammer.

Stewing. A term used in *wire drawing* for the hardening caused by *strain ageing* which takes place during drawing and which lowers the ductility of the wire.

Stibium. The Latin name for *antimony*, hence the symbol *Sb*.

Sticker Hole. The hole which may result when two *stickers* are torn apart.

Sticker Patch. The metal from the *sticker hole* which adheres to the other sheet when two *stickers* are torn apart.

Stickers. (*a*) Ingots which cannot be easily removed from the mould. (*b*) Sheets which have become partially welded together. (See STICKING.) (*c*) An American term for a lump formed on the surface of a casting, due to a portion of the mould face adhering to the *pattern*.

Sticking. The partial welding together of the surfaces of sheet or strip either in *batch annealing* or during *pack rolling*.

Stiefel Mill. A machine for making tubes by hot piercing billets. The rolls of the machine have cantilever supports. (A. 27.)

Stiffness. The resistance of a metal to *elastic deformation*.

Stiffness Test. (See FLEXURE and TOUR MARSHALL TESTS.)

Stilb. A unit of surface brightness equalling one candle power per sq. cm.

Still. A vessel used for the distillation of liquids.

Stitch Welding. A method of *spot welding*, carried out at such a rate that a series of overlapping spot welds make a continuous seam down an overlap of given width, which is usually *tack* spot welded before stitching. Stitch welding is generally used where pressure-tight joints are required or irregular shapes where *seam welding* cannot be used. Unlike *spot welding*, the seam produced is gas- and water-tight. (L. 6.)

Stitching. (See METAL STITCHING.)

Stitching Wire. A mild steel wire, finished mild hard drawn, in sizes from 16 to 26 S.W.G. Usually tin coated before reducing to finished size.

Stock. (*a*) Material in the *blast furnace* in process of smelting. (*b*) The portion of metal cut from a bar or billet that has been allotted to make any given number of forgings. (*c*) The cross-sectional area of a bar being rolled.

Stock Converter. A modification of the *Bessemer converter*, used for the production of steel in quantities of 1 to 3 tons. The charge consists entirely of cold metal, pig iron and scrap, steel scrap, if present, being charged last. The charge is melted by means of oil-fired burners placed within the blast box. As soon as the metal is melted, the metal is *blown*, as in regular Bessemer practice.

Stock Cores. Cores of standard diameters usually made on a core machine and kept on hand, sawn to required lengths. (A. 26.)

Stock Indicator. A steel rod used to determine the position of the *stock line* in a blast furnace. The rod passes in through the *try hole*, the lower end of the rod resting upon the *stock*, whilst the upper end is connected by means of a cable to the *cast house* below.

Stock Line. The level to which the *blast furnace* is charged.

Stoichiometry. The study of the quantitative relationship in which the chemical elements react.

Stokes' Law. The force necessary to propel a spherical body, at uniform speed, through a viscous medium:

$$V = \frac{2ga^2(d_1 - d_2)}{9\eta}$$

where a is the radius of the sphere, d_1 and d_2 the densities of the sphere and the medium, respectively, and η the coefficient of viscosity. V will be in cm. per sec. if g is in cm. per sec.^{2}, a in cm., d_1 and d_2 in g per cm.^{3} and η in dyne-sec. per cm.^{2} or *poises*.

Stolzite. A tungstate of lead ($PbWO_4$).

Stone-Clad. A process of protecting mild steel and cast iron from corrosion at high temperatures. A suspension of insoluble refractories is carried in a boro-silicate matrix and bonded to the metal surface by fusion at about 815° C. (C. 47.)

Stone Wire. A term sometimes used for soft steel wire, usually annealed or galvanized.

Stool. (*a*) The support for a green sand *core* on a *moulding* machine. (*b*) A cast iron, or sometimes copper, plate upon which the *ingot mould* is supported during *teeming*.

Stool Plate. The plate on a *moulding machine* on which *stools* are mounted.

Stool Sticker. A term applied to an ingot which, during *teeming*, and/or subsequent cooling, has become fused to the *stool*.

Stooling. The process of supporting green sand *cores* in *machine moulding* while the pattern is being drawn.

Stop Off Core. A core used to simplify the *parting line* of a *pattern*; i.e. to make it unnecessary to carry the parting line above or below its normal position in order to provide for lugs or cored holes.

Stop Off Plating. A protective barrier against gas absorption from the furnace atmosphere in the selective hardening of parts. (See STOPPING OFF.) (E. 68.)

Stopper. (*a*) (See LADLE). (*b*) (See BRICKING UP).
Stopper Head. (See LADLE.)
Stopper Hole. The hole in a *puddling furnace* through which the *rabble* is inserted.
Stopper Pin. (See LADLE.)
Stopper Rod. (See LADLE.)
Stopping. (*a*) (See BRICKING UP). (*b*) (See SPIKING).
Stopping Bar. (See BOTT STICK.)
Stopping Off. (*a*) A term applied in the case of *patterns* that are larger than the casting required. The shape of the pattern is imprinted in the *mould* but it is stopped off by filling the space not required with sand. This practice is seldom adopted except in the case of straight uniform castings such as pipes or columns. (*b*) The covering of a portion of a surface with a non-conductor to prevent electrodeposition thereon. (*c*) The protection of certain areas from the action of *nitriding* or carburizing effects, e.g. by tinning (in nitriding) or copper plating in *selective carburizing*.
Stopping Up. Plugging the cupola tap hole with clay.
Stored Energy Welding. A resistance welding process in which the weld is made with electrical energy accumulated electrostatically, electromagnetically, or electrochemically at a relatively low rate and made available at the required welding rate. (A. 37.)
Stoughton Converter. A modification of the *Bessemer converter* in which the tuyeres are at one side only and the blast is blown on to the surface of the metal and not through it as in the *Bessemer process*.
Stoving. (See BAKING.)
S.T.P. Standard temperature and pressure, i.e. 0° C. and 760 mm. pressure.
Straight Carbon Steel. A plain carbon steel without any intentional additional alloying elements other than silicon and manganese in proportions sufficient for deoxidation and for conferring good hot working properties.
Straight Draw Machine. A hydraulically operated moulding machine used in the foundry for making the *cope*, or top half of the *mould*.
Straight-Line Hardening. A method of treating rock drill steels in which the bit is heated end-on by flames emerging from an aperture of slightly smaller diameter than itself; the depth of heating is only ¼ in. and the bit is then fully quenched, in water for carbon, and oil for alloy steels. The martensitic zone is practically uniform in depth and is succeeded by the unaltered sorbitic structure with little or no intermediate troostite. (O. 8.)
Straight Polarity. The arrangement of direct current arc-welding leads wherein the work is the positive pole and the electrode is the negative pole of the welding arc. (A. 37.)
Straightening. (*a*) Straightening bar by mechanical means such as *reeling* or *spinning*. (*b*) Straightening wire from a coil by passing it through rolls or spinners. (*c*) Decreasing misalignment between various sections of a forging.
Straightening Machine. (See GAG PRESS.)
Strain. (*a*) The changes in dimensions which accompany the application of *stress*. *Elastic strain* is that strain which disappears on removal of the stress whilst *plastic strain* remains after the disappearance of the stress. (*b*) The ratio of the extension to the original gauge length of the test piece, that is, the change in length per unit original length. It is expressed as a dimensionless ratio. (See also LONGITUDINAL TENSILE STRAIN.)
Strain Age Embrittlement. The brittleness which may occur in certain steels, and particularly in dead mild steels, on *strain ageing*.
Strain Ageing. A phenomenon observed when low carbon mild steel has been subjected to a certain amount of cold deformation and is then allowed to age for a period. The result is an increase in hardness accompanied by a drastic reduction in ductility, as measured, for instance, by an impact test. Even a few per cent of cold-work reduction will produce some age hardening under favourable conditions, but the maximum effect, both as regards increase in hardness, and loss of ductility, is reached with about 15% reduction by cold working. The ageing effect proceeds very slowly at room temperature, and it may take several months to reach the maximum result under such conditions. An increase in temperature will accelerate the change to the extent that reheating to 300° C., for instance, will shorten the time interval to a few seconds. At higher temperatures, the effect diminishes rapidly, softening setting in with a restoration of the impact value. Strain ageing is characteristic of mild steel. (P. 29.) (See also AGEING.)
Strain Gradient. That variation in strain set up in a structure which has been stressed beyond its yield point and has thus suffered varying degrees of deformation.
Strain Hardening. The loss of ductility and gain in strength and hardness resulting from *strain ageing*.
Strain-Line Process. A method of determining the magnitude and direc-

tion of the stresses in various machine parts. A special varnish is applied to the part, which is then subjected to stress. Cracks first form in the varnish at the most highly stressed parts, but they appear at stresses well below the elastic limit. The cracks lie perpendicularly to the direction of maximum extension. Of the two principal stresses at any part, that corresponding to the greatest tensile stress, lies perpendicularly to the strain lines, while the second principal stress, which may be compressive, is tangential to them. To determine the magnitude of the principal stresses, a specially designed extensometer is used. (D. 32.)

Strain·Lines. (See SLIP BANDS.)

Strain Relief Temper. A term used to denote a final thermal treatment when stress-free material is specified or required. Its purpose is to restore elastic properties and minimize distortion on subsequent machining or hardening operations. Ordinarily, no straightening is performed after the strain relief temper. This treatment is usually applied to material that has been heat treated (quenched and tempered) or cold straightened. Normal practice would be to heat to a temperature slightly lower than the tempering temperature used to establish physical properties and hardness.

Strain Rosette Analysis. The normal use of strain gauges is to determine the magnitude of the strain—and hence that of the stress—in one direction at a particular point in a stressed body. It is often necessary, however, to ascertain the stress distribution at that point as well as the magnitude. In this case, there are three unknowns, which when solved, completely define the state of (two-dimensional) stress at any point. These three are the magnitude of each of the two principal stresses and the direction of one of them (the principal stresses being mutually at 90° defines the direction of the other). To solve these three unknowns, three readings are necessary. The physical difficulties of such an arrangement are largely overcome by the use of standard types of multi-gauges, consisting of a number of single gauges mutually inclined to one another. Such an arrangement is known as a strain rosette. There are three common types of rosette in use in this country—the 90° rosette; the *Delta*, or *equiangular rosette*, and the 45° rosette. The 90° rosette consists of two single gauges at 90° to each other and is used where the directions of the principal stress are obvious from physical considerations of the problem, the axes of the gauges being placed parallel to the directions of the principal stresses. The *Delta rosette*, which is the most common, consists of three single gauges, arranged mutually at 60°. The 45° *type*, which is less frequently used, is similar to the 90° rosette with the addition of a third element at 45°. A rosette employed in the U.S.A. is known as the *T Delta* and consists of four gauges, being the ordinary delta gauge with a fourth element at 90° to one of the other three gauges. (F. 8.)

Strained Castings. An American term used to describe the result when molten metal is poured into the mould at too fast a rate or under too great a ferrostatic head, causing the *cope* to rise slightly from the *drag* and resulting in an oversize casting with protruding fins. (A. 26.)

Strainer Core. (See STRAINER GATE.)

Strainer Gate. (*Strainer Core.*) (*Skimmer Core.*) A sand core containing a number of small holes, often placed across the *ingate* or *downgate*, to drop dross and prevent it from entering the casting. (T. 8.)

Strainless Indentation Method. (See ABSOLUTE HARDNESS.)

Straits Tin. Commercial tin containing at least 99·85% pure metal, made from Malay ores.

Strauss Test. A misnomer for the standard *intercrystalline corrosion test* which was developed by the late Dr. W. H. Hatfield, F.R.S., in the Brown-Firth Research Laboratories.

Stray Current Corrosion. Corrosion caused by current through paths other than the intended circuit or by an extraneous current in the earth.

Stray Flash. A welding defect which appears as a small molten blob or crater on the surface of the parent plate. It may be caused by the electrode momentarily touching the plate.

Streak. The name given to the colour of the powder obtained by scratching a mineral with a knife or file or by rubbing the mineral on paper or on an unglazed porcelain surface.

Stream Tin. (See TIN.)

Strength. Resistance to yielding or breaking. (See MAXIMUM STRESS.)

Stress. The load per unit of area. Ordinarily, stress-strain curves do not show the true stress (load divided by area at that moment) but a fictitious value obtained by using the original cross-sectional area of the test piece. Stress is reported in tons per square inch, pounds per square inch or kilograms per square millimetre.

Stress-Ageing. An *ageing* heat treatment, combined with an applied stress,

for alloys containing principally one or more solid solution phases, for the purpose of improving their properties, especially elastic properties and electrical conductivity. The alloys are heated at a temperature below, but within 100° of the recrystallization temperature, and high enough to provide maximum diffusion with elasticity in the crystal lattice (well above 100°), whilst loads of about maximum elastic value (as high as the 0·2% *offset yield* strength) are applied externally for 15 minutes to 20 hours. The treatment can be applied both to steel and non-ferrous alloys.

Stress Analysis. The evaluation of loads developed in components.

Stress Coat Drilling. A technique for the quantitative evaluation of residual stresses. A small hole is drilled into the piece to be tested, which has been previously coated with Stresscoat brittle lacquer; a dye etchant is immediately applied around the hole and the residual stresses are indicated by the pattern of the crazing. (T. 35.)

Stress Concentration Factor. An indication of the theoretical effect of a notch or other stress raiser on fatigue strength of a material. It is the ratio of the greatest theoretical stress near a notch or other stress raiser to the corresponding nominal stress.

Stress Concentrator. An American term for a *stress raiser*.

Stress Corrosion. The term implies a greater deterioration in mechanical properties of a material through the simultaneous action of static stress and exposure to corrosion environment than could occur by the separate but additive action of those agencies. (S. 156.)

Stress Corrosion Cracking. Cracking resulting from the combined effects of *corrosion* and *stress*.

Stress Corrosion Tests. Tests carried out on stressed specimens in corrosive media to determine their susceptibility to *stress corrosion*. As a rule these are carried out either under constant stress or constant strain.

Stress Cracking. Cracks arising in a severely drawn metal due to its being allowed to stand before being given its interstage annealing.

Stress Maximum. (See MAXIMUM STRESS.)

Stress Modulus. Stress divided by strain of any elastic deformation.

Stress Number Curve. (See S-N CURVE.)

Stress Peening. A process which consists of *peening* a part while it is statically stressed in the same direction as it is to be stressed in service. It is claimed that this treatment gives greater improvement in *fatigue* life than does conventional *shot peening*.

Stress Probing. A rapid method for the measurement of stresses in pressure vessels. The test vessel is subjected to a pulsating pressure, and the changes of strain induced are measured by a gauge based on the change of helix angle of a perforated twisted strip. This gauge is held in place by a spring-loaded arm attached by a magnetic clamp to the test specimen. (G. 62.)

Stress Raiser. A term used to characterize any condition which causes considerable local increases of the magnitude of the stress. The most common stress raiser is an irregularity in the section, e.g. a notch, groove, or change in section. Internal notches are formed by *inclusions*, *blowholes*, folds, and other defects in steel and by graphite flakes in cast iron. (S. 1.)

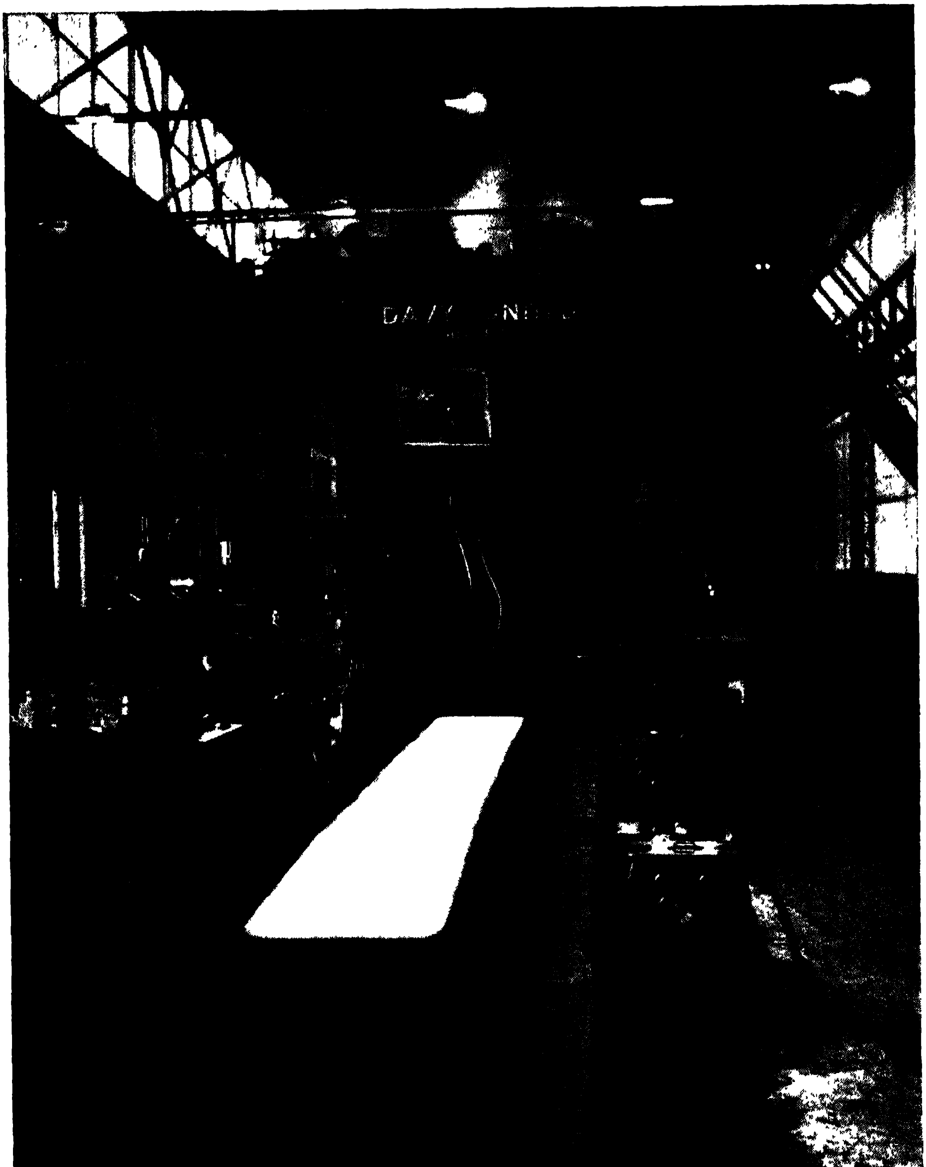
Stress Relaxation. The decrease in stress in a material subjected to prolonged constant strain for a specified time in a *creep test*.

Stress Relaxation Rate. The rate in tons per square inch at which *stress relaxation* occurs. It is usually obtained from a log-log plot of stress relaxation versus time. Stress relaxation rate at a specified time is equal to the slope of the tangent to the curve at that time. Average stress relaxation rate over a specified period of time is equal to the difference between stress relaxation at the beginning and end of that period divided by the amount of time encompassed by that period. Where stress relaxation data are available for several different temperatures and constant strains, a graph of stress relaxation rate at a specified time versus initial stress for various temperatures is sometimes plotted. Such a graph indicates the effects of both temperature and initial stress on stress relaxation rate.

Stress Relief Heat Treatment. (*Stress Relieving.*) A process of reducing residual stresses in a metal object by heating to a suitable temperature, e.g. 600° to 650° C., and holding for a sufficient time for the internal stresses to be released by creeping. After soaking, the structure is allowed to cool slowly in the furnace to a temperature of between 100° and 200° C. and the process of cooling is then completed in still air. This treatment may be applied to relieve stresses induced by *casting*, *quenching*, *normalizing*, *machining*, *cold-working* or *welding*. (W. 16.)

Stress Relieving. (See STRESS RELIEF HEAT TREATMENT.)

Stress Rupture Test. (*Creep Rupture.*) A test in which each of several samples



(Reproduced by the courtesy of Shepcote Lane Rolling Mills Ltd.)

Plate XV.—Rolling strip in hot finishing mill.

of a given material is subjected to a measured tensile stress at a certain elevated temperature and the time required to fail under these conditions of temperature and stress is noted. The data thus obtained are plotted, using time and stress as abscissa and ordinate respectively. The resultant curve shows the time required to bring about failure of the material tested under a given stress at a given temperature. (See RUPTURE TEST.)

Stress Strain Curve. A graph similar to a load extension curve except that the load is divided by the original cross-sectional area of the test piece and expressed as tons per square inch, while the extension is divided by the length over which it is measured and expressed in inches per inch. It is generally used in the *tensile test*. The values of stress are plotted as ordinates and the corresponding values of strain or extension as abscissa.

Stress-Time-Creep-Diagram. A diagram showing the relation of stress and time to *creep* and fracture for a given material at a given temperature.

Stress, Ultimate. (See TENSILE STRENGTH.)

Stretch Forming. (*Stretch Pressing.*) This operation usually consists of clamping a sheet-metal blank along two opposite edges and pressing on the centre with a head of the desired shape without having a corresponding female die; the metal is, of course, stretched into the *plastic range*. (H. 33.)

Stretch Mill. A type of reduction mill, developed for use in the production of seamless tubes, in which overspeed between roll sets induces tension by means of which reductions in diameter of 10% to 12%, per stand, and reductions in wall thickness, can be made.

Stretch Pressing. (See STRETCH FORMING.)

Stretch Rolling. (See STRETCHER LEVELLING.)

Stretcher Flattening. (See STRETCHER LEVELLING.)

Stretcher Head. A large clamp used for gripping the sheet in *stretcher levelling*.

Stretcher Levelling. (*Stretcher Flattening.*) (*Stretch Rolling.*) An operation applied to sheets when the commercial standard of flatness is not satisfactory. The sheets are held at each end by grips, one pair of which is fixed whilst the other is connected to a hydraulic ram and the sheet is stretched to some predetermined permanent extension.

Stretcher Straightening. A process for straightening rod, tubing, and shapes by the application of tension at the ends of the stock. The products are elongated a definite amount to remove warpage. (A. 27.)

Stretcher Strains. (See PIOBERT EFFECT.)

Strickle. (*Loam Board.*) A tool employed to form the desired outline of a *mould* when no pattern is used, as for example, in the case of a circular casting. The strickle rotates on a spindle and sweeps the surface of the mould, the shape of the strickle corresponding to the desired shape of the mould.

Strike. (*a*) (See STRIKE OFF). (*b*) (See STRIKE BATH).

Strike Bath. A solution which will promote bonding or covering by final electroplating. (See STRIKING.) (M. 150.)

Strike Off. (*Strike.*) A straight edge used in *sand casting* to cut the sand level with the top of the *drag* or *cope*.

Striking. The initial electrodeposition of metals prior to the final electroplating.

String Bead. A type of weld bead made without appreciable transverse oscillation. (A. 37.)

String Beading. The deposition of *string beads*. (A. 37.)

Stringer. A microstructural configuration of alloy constituents or foreign material lined up in the direction of working. (A. 27.)

Strip. *Hot rolled steel strip* is steel hot rolled into an approximately rectangular cross-section in which the thickness is small relative to the width, and the length is very great, so that the product is normally coiled up after the last rolling pass. The hot rolling is done from a slab or billet and the whole of the hot rolling from ingot to strip is applied in one direction. (See Plate XV, facing page 411.) The characteristics of *cold rolled strip* are a clean bright surface, entirely free from scale or oxide, with greater precision of thickness than is possible by hot rolling and produced in much thinner gauges than hot rolled strip. Usually, but not invariably, heat treatment is necessary either to restore a soft ductile condition for use in that condition or to permit further cold rolling. (See Plate XIII.)

Strip Casting-On Process. A *composite casting* process, in which an intermediate layer is used, for producing composite metal strip. The process is used for the production of bronze strip coated with white metal or of steel strip with a leaded bronze coating. In this process, the steel strip is first drawn through a molten-tin bath and then through a casting device which is situated in a heated chamber. In this casting device, leaded bronze, or white metal, is cast on to the tinned-steel strip, the thickness

of the bronze layer being controlled by an adjustable blade. The process has proved successful for the production of white metal-coated strip, but presents a number of difficulties when leaded bronze is used for the coating. (S. 31.)

Strip from Iron Powder. Pulverized iron or steel piled up between two horizontal rolls is compressed and forced through the rolling gap by friction. The emerging coherent strip is sintered. The density and mechanical properties can be further improved by repeated rolling and annealing. (N. 2.)

Strip Thermocouple Pyrometer. A *thermocouple* which consists of two thin strips of thermo-electric material which are butted and brazed to form the hot junction. These strips are looped so that the junction projects about $\frac{1}{16}$ in. beyond the level of the supporting legs. Compensating leads of the same material as the strips connect the latter to copper leads in the handle of the instrument, where a thermometer gives the temperature of the cold junction. (H. 34.)

Stripper Guide. (See GUIDE.)

Stripper Punch. In powder metallurgy, a punch, which in addition to forming the top or bottom of the *die cavity*, later moves further into the die to eject the compact. (See PUNCH.)

Stripping. (*a*) Removing the *ingot* from the *mould*. (*b*) In *file* manufacture, the process of removing the surface left after grinding, and preparing the file for cutting. (*c*) Removing coated or electrolytically deposited metal or oxides from the base metal.

Stripping Plate. A plate on a *moulding machine*, on which the *mould* is made, and through which the patterns are drawn from the mould. (P. 1.)

Stroboscope. An instrument for the inspection of objects rotating at high speeds or performing periodic or aperiodic movements. *Stroboflash.* An instrument capable of slowing down or stopping motion over a range of 600 to 14,400 movements per minute. The *Strobotorch* is intended for use in confined spaces or where the instrument must be held in the hand for long periods. (A. 12.)

Stroboflash. (See STROBOSCOPE.)

Strobotorch. (See STROBOSCOPE.)

Stroh Steel Hardening Process. This consists in casting alloy steel together with ordinary soft steel in the same mould, forming one solid casting. (I. 41.)

Strohlein Method. A rapid volumetric method of determining the carbon content of steel. A sample of drillings is burned in a stream of oxygen, the resulting CO_2 and excess oxygen being collected in a burette, and the CO_2 then absorbed. On passing the excess oxygen back to the burette the diminution in volume is read against a scale calibrated directly in percentage of carbon.

Stromeyer Fatigue Testing Machine. A machine in which reverse stresses are applied to the specimen employing rotating unbalanced masses. Mean stresses are superimposed by means of springs. (G. 36.)

Stromeyer Torsion Fatigue Testing Machine. A machine for the application of reversed torsion. A series of cranks give small oscillations to a rocking arm mounted on a shaft which supports the lower end of the specimen, the upper end being gripped by a second shaft to which may be attached two discs. Forced angular vibrations are given to the discs by an electrically driven central shaft connecting the two shafts, the specimen acting as an elastic constraint and thus being subjected to reversed torsional stresses. This machine can be satisfactorily operated at speeds of 1000 r.p.m. (G. 36.)

Strontium. (*Sr.*) An alkaline earth metal which is yellowish in colour and resembles *calcium* in its properties. Its *atomic weight* is 87·63. *Melting point* 771° C. *Specific gravity* 2·6. Strontium carbonate has been sometimes used to the extent of about 1% to 1½% by weight of the furnace charge, in the *basic open-hearth* furnace as a *flux* to increase basicity and fluidity, and for the removal of sulphur and phosphorus. It is claimed to be more efficacious than lime or other alkali carbonates commonly employed for this purpose, but is much more expensive.

Structural. A term applied to the various forms of iron and steel used in buildings, bridges, etc.

Structural Hardening. (See PRECIPITATION HARDENING.)

Structural Mill. A mill chiefly intended for the rolling of *structural shapes*. (B. 51.)

Structural Shapes. (*Sections.*) Hot rolled steel bars of various cross-sectional contours such as channels, angles, bulb angles, I and H beams, T and Z bars, joists and other complicated contours. Sections down to 3 in. are normally considered as *shapes* whilst smaller sizes are commonly referred to as bars. (G. 19.)

Structure. The size and disposition of the constituents of a metal.

Stückofen. (The old *High Bloomery.*) A shaft furnace, now obsolete, 10 to 16 ft. high, round or rectangular in section, about 2 ft. 6 in. wide at the top, 4 ft. midway, and 1 ft. 6 in. at the bottom.

The furnace had one *tuyere* at about 1 ft. 6 in. above the bottom, and a drawing hole about 2 ft. wide at the bottom which was closed except when removing the bloom. In these furnaces there was a great tendency to make cast instead of malleable iron, and to guard against this the carburizing tendencies were purposely restrained, e.g. by charging a large proportion of ore to charcoal. (H. 17.)

Stud Welding. In this process, an arc is struck between the base of the stud and the base metal. When a molten pool of metal exists, the arc is extinguished and the stud driven into the pool to form a weld. Using a gun 5 lb. in weight, a D.C. welding generator is used. With automatic operation, production rates of 1000 studs per hour can be achieved. (M. 55.)

Stupalith. (See LITHIUM CERAMICS.)

Stürzelberger Iron Reduction Process. A process evolved for dealing with pyrite roasting residues rich in zinc (8% to 10%). The direct reduction takes place in a short rotary drum which has a rammed tar-dolomite lining. Lime is added to produce a highly basic slag, the pyrite cinders, pre-calcined, are mixed with coke breeze and fired with pulverized coal burners. The zinc is recovered from the waste gases. The drum works discontinuously in 7-hr. heats and the capacity of such plant is limited in comparison with a blast furnace. The product is a liquid pig iron, which is claimed to be of high grade. (R. 11.)

S.U. Abbreviation for *Sensation Unit.* (See DECIBEL.)

Sub-Boundary Structure. (*Veining.*) A network of boundaries appearing within the main crystals of metals on etching. Sometimes the sub-boundaries are sharp like the main ones, and in other cases they are more diffuse. The small grains defined by the sub-boundaries appear to have a uniform *orientation*, for on deforming, the slip lines cross these boundaries without apparent deviation.

Sub-Critical Annealing. (*Process Annealing.*) Heating to, and holding at, some temperature below the *transformation range*, followed by cooling at a suitable rate.

Subcutaneous Blowholes. *Blowholes* at or near the surface of solidified metal, but covered over with a thin skin of metal.

Sublimate. Solid obtained by the direct condensation of a vapour, without passing through the liquid state.

Sublimation. The process in which a solid is vaporized at atmospheric pressure without passing through the liquid state.

Sublimed. Purified by *sublimation.*

Submerged-Arc Welding. (*Submerged Melt Process, Squirt Welding.*) In this process, a shallow V-shaped groove is used on both the inside and the outside of the steel, no backing strip being employed. A bare copper-plated steel electrode is used and the arc is entirely submerged under a separate loose flux powder, which is continually fed into and over the groove by the welding machine. Some of the flux powder combines with the molten metal, part fuses and forms a refining slag, which solidifies on top of the weld deposit and the remainder of the powder covers the weld and slag, shielding them from atmospheric contamination and retarding the rate of cooling. (E. 28.)

Submerged Combustion. A method of heating by direct contact of the flame from a burner which projects the white-hot gases of the flame directly into, and at any depth below, the surface of a liquid, or of substances which are solid at normal temperature but which may be rendered liquid by the application of heat. (H. 12.)

Submerged Melt Welding. (See SUBMERGED ARC WELDING.)

Suboxide. A compound having less oxygen in its molecule than the basic oxide.

Subscale Formation. (See INTERNAL OXIDATION.)

Sub-Sow Block. A block used as an adapter to permit the use of forging dies that otherwise would not have sufficient height to be used in the particular unit, or to permit the use of dies in a unit where the shank sizes are different.

Substance. The thickness of tin plate expressed as weight per unit area, actually as lb. per 31,360 sq. in. of plate, i.e. lb. per *basis box*. Common substance is 108 lb. per basis box and is designated as I.C. Formerly letters were used to denote substances, X8's for heavier than I.C. and L's for lighter, i.e. 1X = 136 lb., 2X = 156 lb., 3X = 176 lb., etc. (See also LIGHTS and TAGGERS.)

Substitutional Solid Solution. A solid solution in which atoms of one element take the place of atoms of the primary, or solvent, metal.

Sub-Zero Treatment. (*Deep Freezing, Cold Treatment.*) The treatment of steels at temperatures below 0° C. and usually in the region of −72° C. It is claimed that by this treatment the *austenite* is broken down into *martensite.*

Sucking. Local necking of wire during the *drawing* operation.

Suction Pyrometer. An instrument for the measurement of gas-temperature. A *thermocouple*, sheathed if necessary, measures the gas temperature by increasing the convective heat transfer between the gas and the thermocouple to a maximum and reducing the heat losses to a minimum. This is achieved by drawing gas past the thermocouple at as high a velocity as possible without incurring impact errors, and by placing shields round the thermocouple. These shields are heated by the aspirated gas, thus reducing the temperature difference between the thermocouple and its surroundings. This temperature difference may be further reduced, or eliminated by heating the shields electrically, but at high temperatures the refinement becomes difficult to operate, particularly under works conditions. (B. 130.)

Suds. Water base lubricants containing soluble or emulsifying oils or soaps.

Sulf H.F. Process. (See SULFINUZ PROCESS.)

Sulfinuz Process. (*Cassel Process.*) A process which is claimed to provide enhanced resistance to seizure and wear and consists essentially of the impregnation of ferrous surfaces with sulphur. The treatment is performed in a Cassel T-type furnace, or similar salt bath furnace, the bath being composed essentially of cyanide and sulphur compounds. An operating temperature in the range 500° to 600° C. (usually 570° ± 10° C.) is employed. Parts to be treated are dried by warming and are then immersed in the bath for a period which may range from 30 minutes to 3 hours, depending on the material, and the size and shape of the work. A derived process known as *Sulf H.F.* has been developed which is performed rapidly under special conditions, and results in increased surface hardness in addition to the normal increased wear resistance. (L. 11, M. 50d.)

Sull Coating. (*Rusting, Sulling.*) A method of artificially rusting coils of wire rod by spraying with fine jets of water, the requisite hydrated iron oxide coating being formed in a period of about two hours. This provides the steel with a protective film which minimizes the frictional resistance to cold drawing.

Sulling. (See SULL COATING.)

Sulphate. A salt of sulphuric acid.

Sulphide. A compound of sulphur with another element, e.g. hydrogen sulphide (H_2S).

Sulphide Precoats. (See DEVEX PROCESS.)

Sulphite. A salt of sulphurous acid, H_2SO_3.

Sulphur. (*S.*) *Atomic weight* 32·066 ± 0·003. *Melting point* 119° C. *Specific gravity* 2·07. Non-metal, appearing in four allotropic forms. It combines with iron to form ferrous sulphide, FeS, and ferric sulphide Fe_2S_3; in this form its effect is to make the metal *red short*, but combined with manganese its influence is less injurious. For high-quality steels the sulphur content is usually specified as less than 0·05%. In the case of free-cutting steels, sulphur may be added deliberately to improve *machinability*.

Sulphur Bearing Steels. (See SULPHUR.)

Sulphur Prints. A *macrographic* method of examination for the distribution of sulphide impurities in steel in which a sheet of bromide paper after being soaked in dilute sulphuric acid is placed upon the plane polished surface to be examined. The sulphides in the steel react with the acid, liberating sulphuretted hydrogen, which again reacts with the silver salt in the paper, leaving a dark brown stain, thus indicating the distribution of the *sulphur*, and also showing the *flow lines* in forging. The ordinary opaque single sulphur print is at a disadvantage when a large number of reproductions is required. In order to improve this, prints can be made on transparent glossy film paper, the master print being afterwards used for producing any required number of reversed sulphur prints, in which regions of high sulphur stand out effectively as light streaks on a dark background. (O. 12.)

Sulphuric Acid. (*Oil of Vitriol.*) (H_2SO_4.) *Specific gravity* 1·834. *Melting point* 10·46° C. Boiling point 210° to 338° C. Sometimes used for pickling. The dilute acid dissolves steel, aluminium, chromium, cobalt, copper, manganese, nickel and many other metals, and for that reason is largely used in chemical analysis. The uses of sulphuric acid are far too numerous to be listed.

Sulphuric Acid-Fuming. (*Oleum.*) A solution of *sulphuric anhydride* in 100% sulphuric acid. It reacts with water explosively and is used with nitric acid, as a nitrating agent and in explosives.

Sulphuric Anhydride. (SO_3). Sulphur trioxide.

Sulphurous Acid. (H_2SO_3.) A colourless liquid with a suffocating (SO_2) odour. It is used as a reducing agent in chemical analysis.

Sulvanite. A vanadium ore consisting of copper vanadate with some sulphur.

Sump Method. A method for making prints of *microstructures* by placing a

thin celluloid film covered with a solvent on the surface of the specimen; on removing the film the structure is revealed. This method obviates the necessity for cutting a specimen from the body of the material, as is necessary in the case of ordinary microscopic examination.

Super Cooling. Lowering the temperature of a molten metal below its liquidus during cooling. (See LABILE RANGE.)

Super Fines. In *powder metallurgy*, the portion of a powder that is composed of particles smaller than a specified size, currently less than 10 microns. (A. 27.)

Superfinishing. The removal, by means of very fine, fixed, abrasive grains, of the rough fragmented material left on the surface of a metal or alloy by the previous grinding operation, in order to attain high surface finish and dimensional accuracy.

Superfusion. (See SUPER COOLING.)

Superimposed Core. A *core* placed upon and rammed up with a *pattern*. (A. 26.)

Superlattice. (*Superstructure.*) A crystal structure that exists in a solid solution when atoms of the different types fall into an orderly arrangement in relation to one another. (A. 27.)

Supernatent Liquid. The clear liquid lying above a residue which has settled to the bottom of the container. (A. 27.)

Superrefining Process. A *duplex process* in which purified *basic open hearth* metal is transferred to a *basic electric steel furnace*, where it is deoxidized and finished as a high-quality electric steel.

Supersaturation. The condition obtained by the rapid cooling of a saturated solution, solution conditions still being retained.

Super Scottsonizing. (See SCOTTSONIZING.)

Supersonic Reflectoscope. An instrument for the *non-destructive testing* of solid parts for flaws by sending *supersonic sound* waves into the part and observing reflections from the boundaries of the part or from any flaws within it.

Supersonic Testing. (See ULTRASONIC INSPECTION.)

Supersonics. (See ULTRASONICS.)

Supramor. An electro-magnetic flaw detection ink for the rapid detection of both subcutaneous and surface flaws in ferrous metals.

Sure Fire Testing. A method of prestressing rotating discs for turbines in order to induce compressive residual stresses in the bore. The method involves *overspeeding* the discs in a test stand, at a speed which is 10% to 20% higher than will be required in service, before they are assembled in an engine. (D. 35.)

Surface Analyser. An instrument for the measurement of surface finish.

Surface Checking. General breaking and cracking of the surface, which may result from a variety of causes, such as over-rolling, overforming, or atmospheric attack at grain boundaries. (A. 27.)

Surface Cracks. As revealed by deep etching, these usually follow an irregular path and may result from improper handling during heating, *forging* or *rolling*, or during cooling from the finishing temperature. With heat-treated material, surface cracks may be caused by improper treatment, by improper grinding after hardening, or by service stresses.

Surface Crazing. (See CRAZING.)

Surface Hardening. The operation of conferring a superficial hardness to a steel whilst maintaining a relatively soft core. This may be achieved by various methods which are described under their respective headings: *nitriding*, *case hardening*, e.g. *pack*, *liquid* and *gas carburizing*; with *flame hardening*, e.g. *Shorter process*; and *induction hardening*, e.g. the *Tocco hardening process*. (For surface hardening of stainless steels, see MALCOLMIZING.) (C 42.)

Surface Plate. A rigid iron plate with an accurately flat surface. It is used for testing the flatness of other surfaces.

Surface Radiation Pyrometer. A pyrometer claimed to measure successfully surface temperatures up to about 1300° C., its accuracy being about ± 3° C. if the radiation tube is kept within the temperature range 25° to 45° C. The instrument consists of a head about 9 in. long and 4 in. in diam. attached to a long handle. The radiation from the surface whose temperature is to be measured passes through an orifice containing a lens into a radiation tube. The reading is transmitted to a potentiometer by wires running through the handle. The head is water-cooled inside its steel and brass jacket and the working surface is made of polished steel, backed by asbestos, and stands on three small stainless steel legs. (H. 34)

Surface Reflectometer. An instrument for evaluating the polish on a flat metal surface by a single reading. It will give a quantitative comparison of different surfaces in line with the results of visual examination, and is suitable for electropolished surfaces. (O. 7.)

Surface Tension. (*Interfacial Tension.*) The tendency of the surface of a liquid to contract to the smallest area

possible under the existing circumstances, due to the intermolecular attraction of the molecules in the surface behind it, as evidenced in the assuming of spherical form by bubbles and droplets of water and the assuming of the smallest possible area by soap films generally. It is defined as the force in dynes acting on a line one centimetre long lying in the surface of the liquid. A method has been developed of determining the surface tension of high melting point molten metals from the shape of a stationary drop. (B. 29.)

Surface Tester. A microscope expressly designed for the examination of metallic surfaces. The salient characteristic of the instrument is the provision made for comparing two surfaces, which an optical arrangement causes to appear in the field of view side by side without a separating line, thus facilitating the task of judging the condition of a surface.

Surfacing. The deposition of filler metal on a metal surface to obtain desired properties or dimensions. (A. 37.)

Surfagage. An instrument for roughness measurement which measures the arithmetical average of the deviations from the mean surface. (U. 2.)

Surfascope. An instrument used for the optical measurement of roughness of plane and cylindrical metal surfaces.

Surfide Process. A caustic sulphur treatment, in which liners after finish honing, are cleaned and then immersed in a concentrated water solution of NaOH containing a small amount of sulphur. The process is one of etching, any free ferrite being removed from the matrix, while the carbide constituents of the *pearlite* are also reacted upon, fine pearlite being etched away leaving small pits. These pits serve as reservoirs for the lubricant. (Cf. SURFIDING.)

Surfiding. A proprietary name for a method of *induction hardening*.

Surfusion. (See SUPER COOLING.)

Surge Pickling. A method of descaling in which the sheet steel to be treated is placed vertically in the pickling tank and the pickling reagent is surged against the surface.

Surging Lap. (See TEEMING LAP.)

Susceptibility. (*Coefficient of Magnetization.*) Ratio of intensity of magnetization produced in a substance to the intensity of magnetic field to which it is subjected.

Suspended Core. A *core*, having the core seat so formed that it may be suspended from above the *mould*. (A. 26.)

SuVeneer. A proprietary name for steel clad with copper or brass on one or both sides.

Swab. A sponge, or piece of waste hemp or a brush made of teazled hemp rope, used for wetting sand moulds round the edges of a *pattern* before withdrawing it. Swabs are sometimes used for blacking of moulds which might be broken by a brush.

Swabbing. The action of applying water to a *mould*.

Swage. A forging tool used for finishing round or convex surfaces. The top swage is provided with a handle, whilst the bottom swage is held in place by a square shank which fits into a hole in the tail of the handle.

Swaging. A process by which metal is worked into the desired shape by a series of blows rapidly applied by rotating dies. The dies, usually two in number, but sometimes four on large machines, reciprocate rapidly as the spindle on which they are mounted rotates. This means that the finished work must be round but within this limitation swaging can be applied to a wide variety of pointing, tapering, sizing and reducing operations. When the process is applied to the reduction of the diameter of tubes near the ends the term *cressing* is sometimes used. Swaging can be carried out on either hot or cold work, but where possible it is carried out in the cold because of the superior finish and absence of scale. The process yields the same desirable grain structure as that obtained in forging. (A. 54.)

Swarf. Fine particles of metal (usually iron or steel) produced in *machining* or *grinding*.

Swealing. (See WASH HEATING.)

Sweat Cooling. A method of cooling wherein the coolant is forced through the pores of the component under pressure, allowing it to emerge at the surface of the component which is exposed to the external heat source. For this the component has to be porous or has to be provided with a porous surface to which the coolant can be supplied through suitable passages. Materials such as *ceramics*, *ceramals* or sintered metal compacts may be used for the porous component. (M. 162.)

Sweat Out. (*a*) In *powder metallurgy*, the low melting constituent of a *compact* which melts during sintering and subsequently appears on its surface. (*b*) (See LIQUATION).

Sweat Soldering. A process which consists of placing the solder, together with the flux, in between or adjacent to the surfaces to be joined, and then heating the assembly until the solder melts and

makes the joint. The solder, which may vary from 40% to 60% in tin content according to the requirements, is present in the form of a strip or washer, or as a powder mixed with the flux to form a paste which may be applied as a paint. Alternatively, each of the surfaces which are to be united may be pre-tinned. (H. 50.)

Sweating. The appearance on the surface of a compact of some or all of the low melting constituents.

Swedenborg, Emanuel. (Born 1688.) A Swedish pioneer metallurgist and the author of *Opera Philosophica et Mineralia.*

Swedish Aktiebolag Alpha Brinell Machine. In this hardness tester, oil pressure in a small cylinder lifts the cross bar carrying the weights so that the load applying system floats when the correct maximum has been attained and remains so till the pressure is released through the valve. Different weights can be applied to give different pressures. (H. 9.)

Swedish Lancashire Iron. High-class wrought iron made from Dannemora pig, having a typical composition, carbon ·05%, silicon ·037%, sulphur ·006%, phosphorus ·012%, manganese ·108%, copper trace, arsenic ·007%. The tensile strength is of the order of 20 tons per sq. in. with over 30% elongation.

Sweep. (*a*) A piece of wood or iron revolved about a centre to form the surface of the *mould.* (*b*) In annealing, the predetermined curve in a pack of sheets. The sheets are so arranged to ensure flatness in the final product. (*c*) (*Camber*). As applied to strip, the term refers to the deviation of the edge from a straight line.

Sweep Finger. The metal piece by which the *sweep* is attached to the spindle. (P. 1.)

Sweep Work. Moulds made up of pieces of *patterns* and *sweeps* instead of complete patterns. (A. 26.)

Sweepy. The term applied when a rolled piece has a sweeping curve; this is often due to *cold side.*

Swell. A casting defect caused by the displacement of the sand in the mould by the pressure of molten metal. (I. 14.)

Swelling. The term as used in *powder metallurgy*, is synonymous with *growth* or *expansion.*

S.W.G. Abbreviation for Standard Wire Gauge.

Swift. A rotating stand for holding coils of wire during unwinding.

Swift Cupping Test. A test for the deep drawability of metal or steel sheet, the drawability being assessed by determining the maximum diameter of a blank sheet that can be drawn into a cylindrical cup without breaking. The punch, which has a diameter of 2 in., may be either hemispherical or flat-topped. Where the material is intended for an application involving considerable stretching, the hemispherical punch is used.

Swinden and Reeve Test. A weld test in which the baseplate consists of a heavy slab, 2½ in. thick, and of any desired size. It is drilled with 1-in. holes at 4 in. by 3-in. centres and to it are bolted the plates under test. These plates can also be of any desired size, but usually in fillet-weld test the larger is 7 in. wide by 10 in. long, whilst the smaller is approximately 6 in. square. Edges 1, 2 and 3 are fillet welded in position, using ½-in. fillets in the case of ½-in. thick test plates. Edge 4 is then welded with the electrode and technique under test. After cooling to room temperature, the bolts are removed and three ⅜-in. strips are cut through the welded test plate, exposing cross-sections of the weld. It is weld No. 4 which will crack if conditions are suitable for this to occur. It will be clear that the two plates under test are securely restrained from any appreciable movement at the time No. 4 fillet is deposited. The three fillets of weld metal already deposited securely bind the two plates together and the bolts further prevent any movement of the plates by bending away from the underlying slab or by buckling in relation to each other. No. 4 weld therefore cools under extreme conditions of restraint and the shrinkage stresses are thrown largely into the weld itself, and the immediately adjacent plate. Should either weld or plate be prone to cracking, this will be shown by this test. In the most marked cases the crack will be seen at the surface of weld No. 4. (S. 159.)

Swinden, Thomas, D. Met. (1886–1944.) An English metallurgist and a recipient of the Bessemer Gold Medal. He was noted for the wideness of his interests in metallurgical problems. These ranged from researches on alloy steels to investigations in the fields of pyrometry, open hearth practice, the quality of coke, and the properties of refractories.

Swing Grinder. A device for grinding large castings where the work remains stationary. This grinder, too large to be hand lifted, is usually suspended from a hoist.

Swording. The separation of *stickers* by the insertion between them of a long broad-bladed tool.

Sylvester Process. A method for the recovery of manganese and iron from open hearth slag and low grade ores. The process consists of three essential steps. First, a slag is corrected to a molecular lime: silica ratio of about 2, as determined by the following formula:

$$2 = \frac{(CaO - 3P_2O_5)}{SiO_2}$$

This is accomplished by the addition of limestone or silica, as required. The mixture is then fired until the oxides of iron, manganese, aluminium, and magnesium separate into one crystalline phase and the oxides of silicon, calcium and phosphorus separate into another crystalline phase. Second, the oxide phase is separated from the silicate and phosphate phase. Third, the oxide phase is either reduced directly to spiegeleisen or, by a two-stage reduction, to iron and ferromanganese. (S. 162.)

Symmetry. (See AXIS OF SYMMETRY, INVERSION, PLANE OF SYMMETRY.)

Symmetry Element. A general name for *axes of symmetry*, *planes of symmetry*, and centres of *inversion*.

Synchronous Initiation. (*Synchronous Timing*.) In spot, seam and projection welding, the initiation and termination of each half-cycle of welding transformer primary current so that all half-cycles of such current are identical. (A. 37.)

Synchronous Timing. (See SYNCHRONOUS INITIATION.)

Synhibit Process. A method of treating structural steel surfaces for the prevention of rust. Loose scale on the surface of the steel is removed by wire brushing, the tightly adhering scale being left. The brushed surface is then treated with an inhibitor which is claimed to dissolve the remaining rust and to prevent the formation of rust under the surface of the scale that remains. In addition the inhibitor is said to form a surface to which paints adhere well and to prevent the formation of galvanic electric-currents. Inhibitor treatment is followed by the application of a zinc-chromate/iron oxide synthetic vehicle primer. (S. 108.)

Synthesis. The formation of a compound from its elements.

Synthetic. (*a*) Artificially prepared from the component elements or simpler materials; not obtained directly from natural sources. (*b*) In a binary alloy system, an isothermal reversible reaction whereby two liquids form a solid phase during cooling. (A. 27.)

Synthetic Moulding Sand. Any sand compounded from selected individual materials which, when mixed together, produce a mixture of the proper physical properties from which to make foundry moulds. (A. 26.)

Syntron Hammer. Apparatus for the separation of black sheets after annealing, which consists of a lifting magnet combined with a 25-cycle A.C. Syntron hammer having a plunger extending through the magnet. The separator is lowered on to the pile of sheets, and the hammer is operated for a brief period; this loosens the sheets. The magnet is raised a few inches, in short stages, and at each stage the magnet is energized and de-energized. The sheets are thus separated. (I. 25.)

Syphon Brick. A brick for tapping metal from the cupola, the primary object of which is to eliminate the *tapping* and *botting* up of the cupola tap-hole each time metal is drawn off. With the syphon brick, the orifice from which the metal is drawn is continually open to the atmosphere, and the flow of metal is controlled by shutting the blast on and off. The ease of control permits the use of quite small ladles at the cupola, so that there is no need for redistribution from large to small ladles. (D. 52.)

System. One of the six classes into which the thirty-two possible types of crystal and the two hundred and thirty possible types of structure have been divided on the basis of symmetry. They are triclinic, monoclinic, orthorhombic, tetragonal, hexagonal (including rhombohedral and hexagon divisions) and cubic. (A. 27.)

System Sand. An American term for foundry sand used in making *moulds* and which eventually becomes the bulk of the sand used in the mechanical system or mechanized unit. (A. 26.)

T

T. (*a*) British Standard specifications include a T. series relating to tube specifications (*b*) The letter added to certain S.A.E. specifications to denote a *treated steel*.

T.Bar. (See STRUCTURAL SHAPES.)

T Cracking Test. A test for welds, which consists in making a fillet weld on one side of a plate which is arranged to form a T with the base plate and immediately making a second fillet weld on the reverse side of the plate. Such conditions of heat distribution, combined with the restraint of contraction during cooling, will result in the formation of hot cracks if the material is liable to this type of failure.

Ta. Chemical symbol for *tantalum*.

Tables. For conversion tables, Fahrenheit to Centigrade, Metric to Avoirdupois, etc., see Appendix I.

Tachometer. An appliance for measuring the revolutions per minute of a revolving shaft.

Tack Weld. A preliminary weld made at isolated points to hold parts of a weldment in proper alignment until the final weld is completed.

Tacoma Process. An electrolytic method for the production of iron powder. (M. 93.)

Taconite. A magnetic iron ore.

Taggers. Light gauge tinplates not exceeding 55 lb. per *basis box*.

Tagging. (*a*) (*Pointing*.) An operation in the manufacture of wire, in which the ends of the rod are reduced in section in order that they can be passed through the dies of the draw benches. (*b*) A method of preparing a tube after *pilgering* for the ensuing cold drawing operations. The process consists of forming an end on the thick tube which can be gripped by the drawing machine vice.

Tagliaferri Furnace. A melting furnace which combines the principles of indirect arc heating (*Stassano* type) with direct series arc heating (*Heroult* type). Two-phase or three-phase low tension current can be used, the latter being preferred. In this case, the furnace has three roof electrodes, and, during the refining period, arcs pass between them and the bath. Three auxiliary electrodes are also provided, which enter through the sides of the furnace and during the melting period, discharge takes place between these and the main electrodes. The advantages claimed are much greater steadiness of load and more even distribution of heat during melting, whilst the direct arc heating furnishes the high slag temperatures desirable for refining. (J. 27.)

Tail Marks. (*Back End*.) Dimple-like depressions on rolls in strip mills, made by the entry or exit of the strip.

Tail Scale. (See TRICKLE SCALE.)

Tailings. (*Tails*.) (*a*) The gangue or worthless portion of a crushed ore, separated during concentration. (*b*) High boiling impurities less volatile than the solvent being distilled.

Tails. (See TAILINGS.)

Tainton Process. (*a*) An electrolytic galvanizing process, the unusual feature of which is that the zinc is supplied in the form of roasted zinc ores which are first treated with dilute sulphuric acid. The liquor is then filtered to remove undissolved residues which contain iron, lead, arsenic and antimony. The filtered solution passes next into a mixing tank, where powdered zinc is added; this precipitates other impurities such as copper and cadmium, leaving a neutral zinc sulphate solution containing about 220 g. per litre of zinc, which is used in the galvanizing bath. (E. 7.) (*b*) An electrolytic process for the recovery of lead.

Talbot Continuous Process. This is a *pig and ore process*, although scrap is occasionally added. It depends upon the rapid oxidation of the impurities contained in pig iron by a liquid, highly ferruginous slag and is carried out in the basic open hearth furnace, generally of the tilting type. The essential feature of the process is to retain a certain amount of metal in the furnace (1) to dilute the impurities contained in the additions of pig iron, and (2) to supply the heat necessary to keep the slag very fluid. A tilting furnace of 200 tons capacity or over is ordinarily employed, and from about one-quarter to one-third of the finished steel is tapped out at one time. This having been done, additions of ore or iron oxide and lime are made, and after they are properly melted and incorporated in the slag, molten pig iron is run in. A violent reaction takes place, and most of the phosphorus and silicon are eliminated in a few minutes, a large part of the slag running out of the furnace. The bath is then adjusted as in ordinary practice, a part tapped, and the cycle of operations repeated.

Talbot Duplex Process. (See DUPLEX TALBOT PROCESS.)

Talbot Process for Treating Ingots. (*Liquid Squeeze*.) A method of producing sound steel by lateral compression. The ingot is cast into a mould with a refractory lined top. After a suitable interval, the ingot is stripped from the mould and the upper portion is pressed, the outer envelope now being sufficiently strong to retain the pressure, whilst the centre is still liquid. The object of this process is to force out the segregate and thus produce an ingot with minimum impurities. (T. 2.)

Talc. (*Soapstone*.) (*Steatite*.) A mineral, consisting essentially of magnesium silicate. It is used as a dry lubricant.

Tally Mark. A mark or combination of marks indicating the correct location of a loose piece of *pattern* or *core box*. (A. 26.)

Talysurf. An instrument for determining the profile of a cross-section of a surface. A diamond, finished to a radius of 0·0001 in., is traversed across the surface, its up-and-down motion being amplified electrically, the result being

shown on a diagram with a greatly exaggerated vertical scale. (C. 35.)

Tampico Rolls. A combination of *cloth rolls* and fibre brushes employed in the removal of oil from tin and terne plate.

Tamping. (*a*) A moulder's term which signifies the ramming up of the sand around a *pattern*. (*b*) Stopping the *tap hole* of a furnace with clay.

Tandem Mill. (See ROLLING MILLS.)

Tang. The smooth, pointed end of a tool such as a chisel, file or knife, made to fit into a handle.

Tangeite. ($2CaO.2CuO.V_2O_5.H_2O$.) A vanadium ore.

Tangent Modulus. The slope of the stress-strain curve of a metal at any point along the curve in the *plastic* region. In the *elastic* region the tangent modulus is equivalent to *Young's Modulus*. (A. 27.)

Tanna Process. (See ELECTROTHERMIC PROCESS.)

Tantalite. A mineral consisting of tantalate and niobate of iron and manganese (Fe,Mn) $(Nb,Ta)_2O_3$, and the principal source of *tantalum*. All tantalite contains some niobium and all *columbite* contains some tantalum and the two minerals pass from one into the other according to the preponderating element.

Tantalum. (*Ta*.) *Atomic weight* 180·95. *Melting point* 2996° C. *Specific gravity* 16·6. Tantalum is a platinum-white metal when polished, but in the unpolished condition it is often steel-blue, probably due to the existence of a thin film of oxide. It is usually extracted from *tantalite*. In mechanical properties pure tantalum is similar to mild steel, and its cold forming properties are excellent. By suitable working and annealing, tensile strengths ranging from about 20 to 80 tons per square inch can be obtained with Brinell hardness figures of between 40 and 220. It is extremely resistant to corrosive attack by acids and weak alkalis. It has been claimed that in the chemical industry it may be regarded as an alternative material to platinum. As an alloying addition to steel, it is not widely used, since for most purposes, it can be replaced by *niobium*, which, for various reasons, including its lower specific gravity is preferred. For example, tantalum has been added to *austenitic corrosion-resisting steels* as a carbide former for the prevention of *intercrystalline corrosion*, and to *nitriding steels* to accelerate the growth of the nitride layer, but in both cases niobium is more generally used. In the production of *hard metals*, however, tantalum is frequently used, as in this application it is claimed to give additional toughness.

Tantalum Carbide. (TaC.) A compound of tantalum and carbon, possessing great hardness, frequently used in the production of *hard metals*. (See TANTALUM.)

Tap. (*a*) To open up the *tap hole* of a furnace prior to *tapping*. (*b*) The quantity of metal permitted to run out of a furnace or holding vessel at one time. (*c*) A cutting tool on which cutting edges are formed by longitudinal grooves, used for forming internal screw threads.

Tap Bar. (*Tapping Bar*.) A bar, pointed at one end, for opening the *tapping hole* of a furnace.

Tap Cinder. (*Tappings*.) Cinder, generally containing approximately 50% iron tapped from a puddling furnace at the end of the process of wrought iron manufacture.

Tap Density. (*Load Factor*.) The *apparent density* of a metal powder after it has been shaken down by tapping or vibration.

Tap Hole. A hole provided at the back of an *open-hearth furnace* for the removal of the molten steel or slag. In the case of stationary furnaces it must be stopped up very carefully with *refractory* material during the melting process; with a tilting furnace, it is above the level of the *bath* and need not be closed up so tightly.

Tap Hole Plug Stick. Synonymous with *bot stick*.

Tap Out Bar. (See TAP BAR.)

Tap Steel. A high carbon or a high carbon low alloy tool steel used in the manufacture of *taps* and similar tools. It should combine toughness with the ability to take a fine cutting edge.

Taper. (See DRAFT.)

Taper Sectioning. (*a*) A refined metallographic technique for the examination of surface contours and surface structure of metals, in which the section for examination is cut obliquely to the surface, thus obtaining a taper section with the vertical component of the surface contour greatly magnified, relative to the horizontal. The ratio of the magnification in the vertical and horizontal directions in the final section is the cosecant of the angle. Thus, a section cut at an angle of 5 degrees 43 min. would give a distortion ratio of ten. (M. 157.) (*b*) Also used for determining hardness depth curves in case hardened pieces.

Tapiolite. A mineral consisting of tantalates and niobates of iron. It is a source of *tantalum* and *niobium*.

Tapping. (*a*) In steel-making, running the molten steel out of the furnace by knocking out the material from the *tap hole*, if a stationary furnace, or in the case of a tilting furnace by lowering the level of the tapping hole so that the steel will flow out. The molten metal is caught in a *ladle* and poured into *ingot moulds*. (*b*) In drop forging, see RESTRIKING. (*c*) The operation of forming a screw thread in a hole by means of a *tap*.

Tapping Bar. (See TAP BAR.)

Tapping Clay. Clay used for stopping up *tap holes*.

Tapping Hole. An American term for *tap hole*.

Tapping Pin. In welding, a loose-fitting metal plug closing the hole in the *thimble*.

Tappings. (See TAP CINDER.)

Tare. The allowance for the weight of an empty case or container in which goods are packed. The term, actual tare, is used when the case has been weighed separately before packing the goods. Customary tare is the allowance made by established practice where the containers are invariably of uniform weight and size. Estimated tare, as the name infers, relates to an allowance made for containers which have not been weighed but are judged to be of similar weight to others which have been weighed. Super tare is an additional allowance for a packing that exceeds a certain weight.

Target. In X-ray tubes, the part of the anticathode, wholly or predominantly of a single metal, or coated with a substance to be analysed, where the focus lies. (A. 27.)

Tarnishing. The oxidation of metal in dry air. If sulphur compounds are present in the air, the film grows more rapidly. Tarnish is said to be *irised* when it shows prismatic colours.

Tauchhärtung. A rapid method of hardening in which the steel part is placed for a short time in a molten salt or metal bath at well above the hardening temperature; when the surface, but not the core, has been heated above the transformation point the part is withdrawn and quenched. For small parts the heating time is very short, usually less than 1 min. (R. 48.)

Taylor Process. A method for making extremely fine wire by inserting common wire into a glass tube and stretching the two together at a high temperature. (A. 27.)

Tb. Chemical symbol for *terbium*.

T-bend Test. A widely used test for evaluating weldability, in which a double fillet T-shaped specimen is tested as a guided bend specimen without removing any metal from the face of the weld. A special jig is used for bending the specimens and the angle of the head of the T at maximum load is recorded together with the load and type of fracture at failure. (K. 23.)

T. C. *Total carbon*.

Tc. Chemical symbol for *technetium*.

T Delta Rosette. (See STRAIN ROSETTE ANALYSIS.)

Te. Chemical symbol for *tellurium*.

Tear Length Test. In the *Brownsdon* form of this test, two parallel slots are cut 1 cm. apart in the edge of the specimen parallel to the direction in which it is desired to make the tear. The resulting flap is gripped with pliers and pulled so that a triangular-shaped piece is detached from the sheet, the height of the triangle, measured in centimetres, being known as the *tear-length value*. In Jevons' modification of this test, instead of using pliers, the flap of metal is wound back by means of a round, slotted rod. It is claimed that this refinement gives more consistent results, and enables thicker sheet to be tested than when the crude method of pulling by hand is used. The object of the test is to obtain information regarding the tenacity of the material and the severity of directional stresses therein. (Cf. NAVY TEAR TEST.) (J. 16.)

Tear Length Value. (See TEAR LENGTH TEST.)

Tear Test. (See NAVY TEAR TEST.)

Technetium. (*Tc.*) *Atomic number* 43. *Atomic weight* 99. The first element to be prepared artificially by bombarding molybdenum with deuterons, but weighable amounts have been produced by electrolysis. The reduced metal, originally in the form of a silver-grey sponge, tarnished slowly on exposure to moist air, was not dissolved by hydrochloric acid but dissolved readily in nitric acid and aqua regia. It is stated that although its specific activity is not large, technetium may constitute a radiation hazard in some circumstances. (C. 39.)

Technical Cohesive Strength. (See COHESIVE STRENGTH.)

Technical Information Bureau (Ministry of Supply). (*T.I.B.*) Various Government (U.K., U.S.A. and others) documents are available on loan from the Secretary, Ministry of Supply, TPA3/TIB/P and TD, Leysdown Road, Mottingham, London, S.E.9.

Technical Societies. (See Appendix V.)

Technichrome Process. A process for the deposition of hard chrome on ferrous and non-ferrous metals.

Technology. The practice and terminology of an applied science having commercial value.

Tee Bend Test. (See T-BEND TEST.)

Tee Butt Joint. A tee joint made by the use of a *butt weld*. (B. 105.)

Tee Butt Weld. A resistance *butt weld* employed to make a *tee joint*. (B. 105.)

Tee Flash Weld. A resistance *flash butt weld* employed to make a *tee joint*. (B. 105.)

Tee Joint. A joint between two members located approximately at right angles to each other in the form of a T. (A. 37.)

Tee Rail. The normal type of rail which resembles the letter T and is thus distinguished from girder rails. The section consists of a head for the wheel treads and for guiding the wheel flanges, a web for girder strength and a base for bearing and for fastening the rail to its support.

Tee Spot Weld. A resistance spot weld employed to make a tee joint, one of the parts being held either by a contact jaw or in a hollow electrode. (B. 105.)

Teeming. Discharging molten steel from the *ladle* into *ingot moulds*. (See Plates II and VI.)

Teeming Arrest. (See COLD SHUT.)

Teeming Lap. (*a*) (*Single Lap.*) (*Fold. Bootleg Mark.*) A fold in the ingot skin caused by the surface of the rising metal freezing and forming a layer, more extensive than in the case of *ripple*, the layer becoming engulfed as the column of metal rises. The lap is associated with an oxide layer in a more or less horizontal direction within the ingot. (*b*) (*Recurrent Lap.*) (*Surging Lap. Folding. Wash Marking.*) This defect is formed by a series of single laps, which occur mainly in *effervescing steel* and are caused by an intermittent falling back of the metal level in the mould. The condition may give rise to *double skin* in extreme cases. Recurrent lap may also result from aluminium additions made during teeming to retard a too vigorous gas reaction, or from the ladle stream being checked, or from too slow teeming. Recurrent lapping can occur in semi-killed or killed steels and may be attributed to a turbulent stream causing the metal to surge up the mould walls in advance of the rising level of metal. (I. 83.)

Telebrineller. A small portable instrument for the determination of Brinell hardness. It has four components: the instrument, a steel bar of known Brinell hardness, a special microscopic gauge, and a slide rule. To make a test, the bar of known Brinell hardness number is inserted in the tube of the instrument which is placed over the spot to be tested. A sharp blow is struck upon the anvil with any hammer of from 3 to 5 lb. The force of this blow is transmitted by the anvil directly to the bar of known hardness, through this and the impression ball to the surface being tested, thus making a round impression on the face of the metal under test. The relationship between the diameters of the impressions on the bar of known hardness and on the metal being tested gives a means of determining the hardness of the latter. The microscopic gauge and slide rule enables this relationship to be evaluated very rapidly as a Brinell hardness number. (I. 77.)

Tellurium. (*Te.*) *Atomic weight* 127·61. *Specific gravity* 6·24. *Melting point* 450° C. A white lustrous metal resembling *antimony* in crystalline appearance, although chemically it is analogous to *selenium*. Tellurium has been added to steel alone or together with selenium to promote *machinability*. Further, it is a powerful carbide stabilizer, and has been added to cast iron where it is said to increase the depth of chill and to prevent shrinkage. It may be added in small amounts to the molten iron or by the use of cores dipped or painted with washes containing tellurium in suspension. (I. 33.)

Temper. (*a*) The operation of *tempering*. (*b*) The degree of hardness left in a steel after *quenching* and tempering. (*c*) The amount of carbon present in a steel, e.g. razor temper 1·5% C., file temper 1·3% C., die temper 0·75% C. (*d*) The percentage increase in length of a sheet after *cold rolling*. (*e*) The degree of hardness of cold rolled low carbon steel strip as controlled by heat treatment and cold deformation. Strip is produced in a series of tempers from *full hard* or *hard temper* (in U.S.A. No. 1 temper) which is the most heavily cold rolled condition, to *soft* or *dead soft* (No. 5 temper U.S.A.) which is the annealed condition. Intermediate tempers include *skin passed, quarter hard and half hard*. Also the temper of cold rolled non-ferrous alloys. (*f*) The moisture content of a sand at which any certain maximum physical test value is obtained. (*g*) (verb) The process of mixing sands with sufficient water or other liquid to develop its moulding properties. (*h*) The old method of preparing clay, for the production of crucible pots, by treading it with the bare feet.

Temper Bend Test. (See QUENCH BEND TEST.)

Temper Brittleness. (*Krupp Krankheit.*) The loss in notched-bar impact

resistance found in some medium- or low-alloy steels when they are tempered within the temperature range of 350° to 600° C. or slowly cooled from a higher tempering temperature. It is revealed by the notched-bar impact test, but not by the tensile test. Temper brittleness is reversible and the tough condition can be recovered by heating to above the critical range followed by rapid cooling.

Temper Carbon. (*Annealing Carbon.*) The free or graphitic carbon which comes out of solution usually in the form of rounded nodules in the structure during *graphitizing* or *malleablizing.* (A. 28.)

Temper Colours. The colour of the oxide layer which forms on heating bright steel at temperatures of the order of 200° to 400° C. It is sometimes used as an indication of the temperature when tempering hardened tool steel, etc., the colours changing with increase of temperature. Approximate temperatures for plain carbon steels are:

Light Straw	210° C.
Straw	225° C.
Dark Straw	240° C.
Yellow Brown	255° C.
Red Brown	265° C.
Purple	275° C.
Violet	285° C.
Cornflower Blue	295° C.
Pale Blue	310° C.
Grey	330° C.

It should be noted that the above temperatures apply to normal tempering times, but the formation of the oxide film is also affected to some extent by time, and tempering for an excessively long period, even at a temperature as low as 220° C., would eventually produce a temper colour which would pass from straw, through brown to purple. Higher temperatures are required to obtain the same colours in the corrosion- and heat-resisting steels.

Temper Hardening. (See TEMPERING HARDNESS.)

Temper Rolling. (*Skin Rolling.*) The continuous rolling of cold reduced steel strip under tension with the object of producing flat strip of specified gauge and with certain mechanical properties. (See TEMPER.) Temper rolling usually follows after the sequence of hot rolling, pickling, cold reducing and annealing. (M. 155.)

Temper Stressing. Quenching in water from the tempering temperature.

Temper Time. In resistance welding, that part of the postweld interval during which a current suitable for tempering or heat treatment flows. (A. 37.)

Temper Water. Water added to *moulding sand* to give the proper moulding consistency.

Temperature. The degree of hotness or coldness of a body in relation to an arbitrary zero. (See CELSIUS, CENTIGRADE and FAHRENHEIT SCALES.)

Temperature Conversion. To convert Fahrenheit to Centigrade, subtract 32, multiply by 5 and divide by 9. To convert Centigrade to Fahrenheit, multiply by 9, divide by 5, and add 32. (For Temperature Conversion Tables, see Appendix I.)

Temperature Differential. The difference in temperature between the core and the surface of a metal during the quenching or other operation.

Temperature-Impact Curve. A graph showing the relationship between *notch impact value* and the temperature of testing.

Temperature Resistance Coefficient. The ratio of the change of resistance due to a change of temperature of 1° C. to its resistance at 0° C.

Temperature Stresses. *Internal stresses* set up when the deformation normally caused by change of temperature is hindered or prevented, the intensity of the stresses being proportional to the degree of normal deformation that is prevented.

Tempering. (*a*) The process of reheating hardened, normalized, or mechanically worked steel to some temperature below the transformation range, and holding for a suitable time at that temperature, followed by cooling at a suitable rate. The object of tempering is to decrease the hardness and to increase the toughness to a greater or less degree. The term *draw* or drawing, as sometimes employed in the U.S.A., is to be deprecated. (See also STRESS RELIEF HEAT TREATMENT.) (*b*) (See TEMPER). For effect of tempering see Appendix III.

Tempering Hardness. On tempering high speed steels there is an increase in hardness, at about 510° C., which rises rapidly up to about 600° C. This hardness, which often exceeds that of the as quenched condition, is known as *secondary hardness* and the process as *temper hardening.* (See RED HARDNESS.)

Tempilac. A temperature sensitive paint which changes colour on attaining a certain temperature.

Tempil Pellets. Tablets composed of substances of known melting point used as temperature indicators. They are available in a series covering a range of temperatures up to about 900° C.

Tempilstiks. Temperature indicating crayons made to cover a range of temperatures. The workpiece is marked

with the crayon before heating begins, the tempilstik mark liquefying when the appropriate temperature is reached. Tempilstiks are available to cover temperatures at intervals between 45° and 926° C.

Template. (*Templet.*) A thin plate, cut to the shape or profile required on a finished surface, and used as a gauge or pattern in machining or, for example, in checking the dimensions on forgings or dies.

Templet. (See TEMPLATE.)

Templin Axial Stress Fatigue Testing Machine. In this machine, the specimen is alternately stretched and compressed. The load applied is measured by the deflection of an elastic loop of steel in series with the specimens. The range of stress can be adjusted by nuts acting to place a variable amount of initial load on the specimen. Each machine can apply cycles of stress on two specimens at the same time. (A. 35.)

Templin Grip. A spherically seated wedge type of shackle for clamping the ends of flat test pieces in the tensile machine.

Tempo Brazing. A form of resistance brazing characterized by its carefully controlled temperature-time factor. It is stated to be particularly suitable for non-ferrous cold-worked materials.

Temporary Deflection Test. A test imposed on steel tubular traction poles to verify that they are capable of sustaining the forces to be imposed on them in service. It is specified that upon application of the appropriate load, the temporary deflection, measured at the point of application of the load, should not exceed 6 in. (B. 100.)

Temporary Hardness. A form of hardness of water that can be removed by boiling. It is caused by the presence of bicarbonates of calcium and magnesium.

Temporary Magnets. (See MAGNET.)

Temporary Pattern. A pattern used to produce one or two castings only and, therefore, made as cheaply as possible.

Tenacity. The *maximum tensile stress* which a material is capable of withstanding; *tensile strength.* (See also SPECIFIC TENACITY.)

Tenon End. (See ROLLING MILLS.)

Tensile Impact Test. The determination of the resistance of a material to high velocity tensile impacts. In a machine, developed by H. C. *Mann,* for carrying out this test, a variable speed fly wheel delivers a tensile impact to a test bar similar to the bars used in ordinary tensile tests. (See also MANN TENSION IMPACT TESTING MACHINE.)

Tensile Strength. (*Maximum Stress, Ultimate Tensile Stress.*) The maximum tensile stress which a material is capable of withstanding. In practice, it is considered to be the maximum stress developed by a specimen representing the material in a tensile test carried to rupture, under definite prescribed conditions. Tensile strength is calculated from the maximum load carried during a tension test and the original cross-sectional area of the specimen. (A. 28.)

Tensile Stress. The tensile load per unit area of original cross-section, within the gauge boundaries, carried by the test specimen at any given moment. (A. 28.)

Tensile Stress-Strain Curve. The curve obtained by plotting *tensile stresses* as ordinates against corresponding longitudinal tensile strains as abscissae for the entire course of a tension test. (A. 28.)

Tensile Test. A test in which specimens are subjected to an increasing tensile pull, until they fracture. A *stress-strain curve* may be plotted and the *limit of proportionality, proof stress, yield point, maximum stress, elongation* and *reduction of area,* determined.

Tensile Testing Machine. A machine for applying a tensile load to a test piece, by means of hand- or power-driven screws or by a hydraulic ram. The load is usually measured by a poise weight and a calibrated lever.

Tension. (*a*) Stress which tends to cause extension of the bar, strip, wire or other part to which it is applied. (*b*) The pull applied to the strip in a rolling mill either by a power-driven coiler, or by a preceding or subsequent stand in a tandem mill. If the pull tends to draw the strip forward out of the rolls it is a front or wind tension, if it tends to pull it back on the side where it is entering the rolls, it is a back or drag tension. The tension in this sense is expressed in terms either of a force applied to the cross-section or a stress per unit area of the cross-section.

Tension Electric Process. A process for the heat treatment of long steel members. The member is held at the ends by metal grips, and is thus suspended, usually in free air. It is heated by the passage through it of an electric current which brings it very rapidly to a uniform temperature, which is maintained for a few seconds; the current is then switched off and the member is cooled sufficiently rapidly to ensure adequate hardening. Tempering is effected by a smaller current maintained for a longer time. (W. 78.)

Tension Impact Tester. A machine for measuring the energy employed in breaking test pieces by impact tension. A heavy tup falls freely along a vertical guide until it impacts a fitting morse taper at the lower end. The upper end of the guide is fixed to one extremity of the test piece, the other end of which is secured to the framework of the machine. When the test piece fails, the tup and guide-rod plunge into an air cylinder and are brought to rest by the compression of the air in the latter. The traverse of the tup before it is stopped is marked autographically. By calibrating the machine with test pieces of known strength and measuring relevant dimensions the energy absorbed in breaking the specimen is found. (V. 13.)

Tension Reel. A device employed, e.g. in rolling steel strip, for maintaining a constant tension on the metal.

Tensiostat. A device having the property of offering constant resistance over a range of strains or displacements. It is approximated by a slender column pinned at both ends, and loaded axially to the critical buckling load. (P. 10.)

Tensometer. A miniature portable *tensile testing machine* which automatically records *load-extension diagrams* throughout the test.

Tephroite. A manganese ore containing about 65% MnO.

Tepla-Masse. A coal-tar pitch, for protecting the outside of steel tubes against corrosion and bacteria. (D. 2.)

Terbium. (*Tb.*) *Atomic weight* 158·93. *Specific gravity* 8·33 (computed). *Melting point* 327° C. A metallic element, and a member of the rare earth group. It is trivalent.

Terminal. A point on an electric circuit by which it can be connected to another circuit or piece of apparatus.

Terminal Hardness. The load obtaining at the maximum on the load/Brinell hardness curve. It is calculated from the diameters of the impressions produced under two or three different loads by applying Meyer's power law. (D. 39.)

Ternary Alloy. An alloy consisting of three principal elements.

Ternary Diagram. A diagram showing the constitution of a system containing three components.

Terne. An alloy of lead with up to about 25% of tin.

Terne Plate. Steel sheet coated with a tin-lead alloy, the coating being carried out by the *hot dip process*.

Terni Furnace. A modification of the *open hearth furnace* in which the essential feature is the port design. The airports gradually increase in cross-section until they are as large as the hearth itself, thus practically eliminating turbulent flow in the furnace. This is claimed to result in increased output and reduced fuel consumption. (F. 13.)

Tervalent. (*Trivalent.*) Having a *valency* of three.

Tessellated Stresses. Self-compensated stress systems in which the anisotropy of the single crystals of most materials and the differences between the bulk physical properties of the components of compound solids readily cause internal self-compensated stress systems to develop round such centres as crystals or components of the compound structure, respectively. (L. 7.)

Tesseral. The cubic system in crystals.

Test Blocks. (*Coupons.*) Pieces for the provision of tensile test blanks for cast steel. Cast-off test blocks are cast in the same box as the casting, from the same *downgate* but with independent *ingates*. Cast-on blocks are incorporated as integral sections of the castings as distinct from test pieces cut from the casting itself. Separately cast test blocks are moulded and cast independently from the casting. The term is also applied to the integral portions of forgings and castings taken for testing. (P. 48.)

Test Coupons. (See TEST BLOCKS.)

Test Lug. An American term for a lug cast as part of the casting and later removed for testing purposes.

Test Paper. An absorbent paper, impregnated with an indicating solution, e.g. *litmus paper*, used in chemical analysis.

Test Piece. A sample *test bar*, or *test strip*, as finally prepared for *testing*.

Test Sample. That portion of a material taken for testing.

Testing. *Mechanical testing* consists of submitting samples of the material to one or more of the conditions which it is designed to withstand without failure in service, and increasing the severity of such conditions to destruction of the material. From the behaviour of the metal under test, certain numerical relationships between the conditions of test and of the material (e.g. *stress* at moment of fracture) are obtained, and generally accepted as representing fundamental properties of the material. Other forms of testing include *corrosion* and chemical testing and testing for freedom from external and internal defects.

Tetartohedral. Concerning crystals. Having only one-fourth of the symmetry elements possible to the crystal system in which the crystal belongs. (A. 27.)

Tetrad. An element having a *valency* of four.

Tetragonal System. The crystallographic system in which all the forms are referred to three axes at right angles; two are equal and are taken as the horizontal axes, whilst the vertical axis is either longer or shorter than these. It includes such minerals as *zircon* and *cassiterite*.

Tetrahedron. A four-faced, solid figure, contained by four triangles; a pyramid with a triangular base.

Tetravalent. Having a *valency* of four.

Texture. The pattern of preferred orientation occurring in wrought or cast metal. (A. 27.)

Th. Chemical symbol for *thorium*.

Thallium. (*Tl.*) *Atomic weight* 204·39. *Specific gravity* 11·85. *Melting point* 300° C. A tin-white, *crystalline*, malleable metal similar to lead, but so soft that it can be scratched with the finger-nail. When freshly cut it possesses a metallic lustre, but this rapidly tarnishes and becomes dull. It does not react with water unless raised to a red heat, and at about the same temperature it volatilizes with the formation of brown fumes of oxide. Thallium has a transformation temperature of 232° C. The chief use of the metal is in the production of optical glass of high refractive power. Thallium is also employed as an addition to lead-base bearing alloys to increase their resistance to deformation and corrosion.

Theorem. In mathematics a proposition to be proved; in analysis and algebra a rule or law.

Theoretical Electrode Force. (See ELECTRODE FORCE.)

Theory. An explanation of certain phenomena i.e. a series of hypotheses found to be consistent with one another and with observed phenomena but not yet proved by experiment.

Therm. A unit of heat. It is equal to 100,000 *B.Th.U.* and is the recognized unit for the sale of gas.

Thermal Analysis. A method of determining the transformation point in a substance by recording the temperatures at which *endothermic* and *exothermic* effects take place on heating or cooling.

Thermal Bursts. (See FLAKES.)

Thermal Capacity. (*Heat Capacity.*) The amount of heat required to raise the temperature of unit mass of a body 1° C.

Thermal Conductance. (See CONDUCTANCE, THERMAL.)

Thermal Conduction. (See CONDUCTION, THERMAL.)

Thermal Conductivity. (See CONDUCTIVITY, THERMAL.)

Thermal Conductor. (See CONDUCTOR, THERMAL.)

Thermal Contraction. (*a*) The decrease in volume taking place during cooling. (*b*) As applied to a sand mixture, the decrease in linear dimension accompanying a change of temperature.

Thermal Convection. Transmission of heat through a fluid (liquid or gas) by means of fluid currents.

Thermal Dissociation. A reversible chemical change induced by heat.

Thermal Electromotive Force. The *electromotive force* generated when the junction of two dissimilar metals is heated.

Thermal Etching. A method of etching in which a polished metal specimen is maintained at a high temperature, and grooves develop where the crystal boundaries intersect the surface, and in some atmospheres striations form on the crystals. (S. 63.)

Thermal Expansion. (*a*) The increase in dimension on heating. It is usually expressed as the *coefficient of linear expansion* which is the ratio of the change in length per degree to the length at 0° C. (*b*) As applied to a sand mixture, the increase in a linear dimension accompanying a change of temperature.

Thermal Fatigue. Failure resulting from rapid cycles of alternate heating and cooling.

Thermal Gradient. The variation in temperature with distance. A thermal gradient exists across a weld as it is being made, the temperature at the weld pool being that of the molten metal whilst the plate at some distance from the seam is possibly still at room temperature.

Thermal Hysteresis. (See TRANSFORMATION RANGE.)

Thermal Number. A value applied to measure the efficiency of metal cutting. In metal cutting much of the mechanical energy expended is converted into heat, the distribution of which determines the efficiency of the cutting operations. In general, this distribution depends upon a thermal number (R_1) defined as:

$$R_1 = V_c t_1 / k$$

where V_c = cutting speed in ft. per min.
t_1 = feed in in. per rev. or in. per min.
k = thermal diffusivity of the work material.

As k is constant as long as the temperature of the work material does not change materially, the thermal number can be considered as the speed/feed product ($V_c \times t_1$), or more appropriately as a work number, i.e. the

amount of metal removed at a given depth of cut per unit of time. (T. 46a.)

Thermal Ohm. (See THERMAL RESISTANCE.)

Thermal Re-Flowing. (See FLOW BRIGHTENING.)

Thermal Resistance. Resistance to the flow of heat. The unit of resistance is the *thermal ohm* which requires a temperature difference of 1° C. to drive heat at the rate of 1 *watt*.

Thermal Resistivity. (*Specific Thermal Resistance*.) A measure of the property of a material which resists the flow of heat therein. It is usually expressed in *thermal ohms* per centimetre cube.

Thermal Shock. Stress developed by rapid and uneven heating of material.

Thermal Sintering. Moulding by sintering without prior compacting.

Thermal Stability. As applied to moulding materials, the term refers to the resistance of the material to drastic changes in temperature, as for example, when molten metal is poured into the mould.

Thermal Stresses. Stresses in metal resulting from non-uniform distribution of temperature. (A. 27.)

Thermal Transmission. The passage of heat by means of the combined effects of conductivity, radiation and convection.

Thermel. A thermoelectric thermometer.

Thermindex. Temperature indicating paints, covering the range 80° to 800° C. While the change of colour is dependent mainly on the temperature obtained, the length of time to which the colour is exposed to that temperature also has a slight effect. Thermindex colours have been standardized on an exposure period of 10 minutes, and the temperatures shown are those which produce the colour change within this interval.

Thermion. *Ion* emitted from a hot body.

Thermionic Emission. Emission of electrons from a heated electrode.

Thermionic Valve. An evacuated glass or metal envelope containing a heated cathode emitting electrons, which are driven to an anode by an applied voltage and by using additional electrodes, or grids, various electrical characteristics can be achieved.

Thermionics. The science dealing with the emission of electrons from hot bodies.

Thermistor. A temperature-sensitive resistance element of metallic oxide, whose electrical resistance decreases with increase in temperature. It has a temperature coefficient considerably greater than that of a pure metal. The large negative temperature coefficient of thermistors has led to their use in thermometry, for the measurement and control of temperature, for compensating for changes in temperature and for compensating for the electrical effects of temperature changes upon components. (B. 31.)

Thermit. A mixture of various oxides, and aluminium powder, with or without other alloying metals, all in a state of fine division used in the *aluminothermic process*. The exothermic reaction resulting from the use of thermit is employed in various processes, as for example *Thermit Casting* and *Thermit Welding*. There are various types of thermit mixtures, e.g. *Plain Thermit*, consisting of iron oxide and finely divided aluminium; *Forging Thermit*, which consists of plain thermit with the addition of carbon, manganese, nickel, or other alloying metals, and mild steel, and *Cast Iron Thermit*, in which ferro-silicon and mild steel are added to the normal thermit mixture.

Thermit Casting. A process of producing steel castings by means of which molten metal at a temperature of approximately 2400° C. is produced in a period of 20 to 25 seconds by the strong chemical reaction between iron oxide (mill scale) and powdered aluminium. Quantities of steel ranging from a few pounds to a ton may be produced and the operation may be carried out wherever desired. (S. 132b.)

Thermit Combined Weld. A type of weld used with tramway and railway rails where the heads of the rails are welded by the *pressure thermit process*, with or without the interposition of a *shim*, and where, simultaneously, the feet and webs of the rails are joined by the *fusion thermit process*.

Thermit Crucible. The vessel in which the *thermit reaction* takes place. (B. 105.)

Thermit Fusion Welding. A *fusion-welding* process where the welding heat is obtained from liquid steel resulting from a *thermit reaction*, the steel so produced being used as the *filler metal*.

Thermit Mould. A mould formed around the parts to be welded to receive the molten metal in *thermit welding*.

Thermit Reactions. *Exothermic*, self-propagating processes in which finely-divided aluminium powder is used to reduce metal oxides to free metals. (See ALUMINOTHERMIC PROCESS and THERMIT.)

Thermit Welding. A process by which molten steel, resulting from a *thermit reaction*, at a very high temperature is poured into a mould surrounding the parts to be welded, the excessive heat of the added steel fusing the separate

pieces into a homogeneous whole. (B. 8.)

Thermochemical Equation. An equation which sets out the changes in heat energy together with the chemical changes involved in a reaction.

Thermochemistry. The science dealing with thermal changes taking place in chemical reactions.

Thermocolours. A series of powders which are claimed to have the property of changing their initial colour immediately on reaching certain temperatures. These thermocolours have either one or more colour changes and are dependent on time. The colour changes of the powders painted on a heated body indicate its surface temperature. Only some of these thermocolours return to their initial colour after cooling, while other paints which are not reversible indicate the highest temperature attained by the body. (H. 34.)

Thermocouple. A device for measuring temperature in which a pair of electric conductors are so joined as to produce a *thermoelectric effect*. When the ends of two dissimilar metals or any pair of electrical conductors, are joined, a thermoelectric effect is produced which causes an electric current to flow round the circuit formed by the two wires, the magnitude of the current being proportional to the difference in temperature between the hot and cold junctions. The points of contact are known as *thermojunctions*, the joint at the heated end as the *hot junction*, whilst the unheated joint is the *cold junction*. This phenomenon has been applied to the measurement of temperature. In general, thermocouples can be divided into two types: *precious metal*, and *base metal couples*, the former being used for high temperatures where resistance to oxidizing conditions is involved, the base metal couples being used for lower temperatures. The *Le Chatelier* platinum, platinum-rhodium thermocouple is still used for the measurement of temperatures from 300° to 1600° C. The *Pallaplat* thermocouple, which has one branch made of an alloy of gold, palladium, and platinum, and the other of platinum and rhodium, is less costly and more sensitive. Its durability is, however, inferior and its application limited to the measurement of temperatures below 1000° C. Alloys of platinum with rare metals such as rhenium, osmium, tungsten and molybdenum have been used to measure temperatures of over 1500° C. Rhodium may be added to prevent such alloys from becoming fragile through recrystallization at high temperatures. A thermocouple of pure iridium for one branch and an alloy of 60% rhodium and 40% iridium for the other, may be used for temperatures up to 2000° C. *Nickel-carbon couples*, which consist of a nickel wire in a tube of carbon, insulated by a tube of porcelain, provide an example where one of the conductors consists of a non-metal.

Thermodynamics. The science dealing with the relationship between heat and work.

Thermo Elasticity. The variation of the temperature of a material when stress is applied. (C. 40a.)

Thermoelectric Effect. (*Seebeck Effect.*) The increase in *e.m.f.* due to a difference of temperature between two junctions of dissimilar conductors in a circuit.

Thermoelectric Element. One of the two dissimilar conductors constituting a *thermocouple*.

Thermoelectric Inversion. The decrease in *e.m.f.* of a *thermocouple* when the temperature increases above a certain degree.

Thermoelectric Method. A method of determining the *critical points* in steel by plotting the changes in electrical properties against the changes in temperature.

Thermoelectric Power. Quantity measured by the *electromotive force* produced by a thermocouple for unit difference of temperature between the two junctions.

Thermoelectric Pyrometer. An instrument consisting of a system in which there are three main components, namely: (1) the *thermocouple*, (2) the extension leads, and (3) the measuring instrument.

Thermoelectric Sorting. A method of metal sorting in which a thermojunction is formed between the unknown and the standard material, and the resulting *thermo electromotive force* examined. (H. 2.)

Thermoelectricity. Electricity generated by heating the junction between two dissimilar conductors. (See THERMOELECTRIC EFFECT.)

Thermo Electromotive Force. The *electromotive force* due to a *thermoelectric effect*.

Thermoflux Method. A *thermoelectric* device for measuring the thickness of the shell plate of boilers and pressure vessels for corrosion-testing purposes, in which the measurement is made by applying heat at a controlled rate for a limited time, and measuring the resulting rise in temperature. For steel boiler plate, the heat is most conveniently generated in the metal itself by an alternating-current magnetic yoke held in contact with the surface. A thermocouple is applied between the

legs of the yoke, and the rise in temperature after a definite length of time is used as the thickness indication. (F. 23.)

Thermogalvanic Corrosion. A form of electrochemical corrosion caused by differences in temperature in systems which are normally stable. (B. 48.)

Thermograph. (See THERMOGRAPHY.)

Thermography. A term applied to the technique of visually ascertaining and obtaining a permanent photographic record of heat distribution in solid bodies and in fluids. A *thermograph* is the device used for recording the heat distribution. (E. 67.)

Thermolabile. Susceptible to destruction by heat.

Thermopile. A number of *thermocouples* connected in series so that their electromotive forces are additive.

Thermoplastic. The property of softening under heat; a thermoplastic substance is adequately rigid at normal temperatures and under normal conditions of stress, but is capable of deformation under heat and pressure.

Thermoscopic Bars. Small ceramic bars of specified composition which soften at certain temperatures. (See HOLDCROFT THERMOSCOPE BARS.)

Thermosetting. The property of becoming hardened by the application of heat.

Thermosorter. (See TRIBOELECTRIC SORTING.)

Thermostat. A bath which is automatically maintained at a constant temperature.

Thermostat Metal. (See BI-METAL.)

Thermostatic Control. An automatic device for maintaining an enclosure at a constant temperature. It often consists of some expansible element which automatically cuts off the heat supply (gas or electric) when the temperature exceeds the required value.

Thick Ends. Excessive thickness at the ends of a coil of strip. It is generally caused by uneven tension during rolling.

Thimble. (*a*) A cast iron or steel vessel mounted on a railway truck. (*b*) In welding, a renewable *collar* of magnesite inserted in a *stone* and having a hole through which the molten metal is tapped into the mould at the completion of a *thermit reaction*. (*c*) A grooved metal fitting to protect the eye of a wire rope.

Thixotropy. (*a*) That property of a body by virtue of which its consistency is reduced by previous deformation. (*b*) The rate of change of viscosity of a suspension as the rate of shearing strain varies.

Thomas Iron. The name given on the Continent to pig iron containing about 2% phosphorus.

Thomas Process. The name used on the Continent for the *Basic Bessemer Process*. (See BESSEMER PROCESS.)

Thomas, Sidney Gilchrist. (1850–85.) The inventor of basic linings for the Bessemer converter which enabled phosphoric iron to be blown and made into steel, leaving the phosphorus in the slag. (G. 33a.)

Thomas Steel. The name used on the Continent for *basic Bessemer steel*.

Thomson Coefficient. The ratio of Thomson e.m.f. in a metal to the corresponding temperature difference. (See THOMSON EFFECT.)

Thomson Effect. (*Kelvin Effect.*) The e.m.f. produced by a difference of temperature between two portions of one and the same conductor, and the liberation (or absorption) of heat taking place when a current flows from a hotter to a colder portion of the same material.

Thoria. (See THORIUM OXIDE.)

Thorium. (*Th.*) *Atomic weight* 232·05. *Specific gravity* 11·5. *Melting point* about 1850° C. A greyish-white crystalline metal belonging to the titanium group. When ignited it burns brightly in air, to produce the oxide, *thoria*. It is an extremely soft metal (Rockwell B10), which is comparable with annealed copper. Thorium can be cold-rolled into wire or sheet; and can also be cold-swaged, but cannot readily be cold-drawn, because of its relatively low tensile strength. It has been used in photoelectric cells, glow-tube cathodes and X-ray targets. It is radioactive, producing radium and thorium emanation as one pair of products. In steel, thorium is claimed to have a desulphurizing effect, but it has been found that steel loses its heat treatability if the thorium content amounts to about ten times that of the carbon content and is, therefore, sufficient to convert all the carbon to thorium carbide, and that the presence of more than about 0·1% thorium in steel is likely to be detrimental. With regard to cast iron it has been claimed that the addition of 0·2% to 1·0% of thorium reduces the viscosity and tends to improve the bend and tensile properties.

Thorium Oxide. (ThO_2.) A high temperature refractory with a melting point of more than 2800° C. It is also known as *thoria* and is one of the oxides which is responsible for the efficiency of the Welsbach gas mantle. Thoriated tungsten wire—made by adding 1% to 2% of thoria to the tungsten oxide

before reduction to metal—has been used for filaments for radio valves and electric lamps, giving greater electron emission per unit area than pure thorium wire and having some other advantages.

Thoron. (*Tn.*) An inert gaseous product of thorium emanation.

Thread Rolling. Forming external threads on screws of bolts by passing between grooved rolls (*cylindrical die rolling*) or die plates (*flat die rolling*). Threads so produced are claimed to possess greater strength than machine-cut threads, due to the effect of cold working during the rolling operation.

Three-High Mill. (See ROLLING MILL.)

Three o'Clock Welding. A *submerged arc welding* process which allows working from both sides. It is said to overcome previous difficulties of directing the electrode and retaining the flux and molten metal in a joint not lying flat. (W. 24.)

Throat Depth. In a resistance-welding machine, the distance from the centre-line of the electrodes or platens to the nearest point of interference for flatwork or sheets. In the case of a seam-welding machine with a universal head, the throat depth is measured with the machine arranged for transverse welding. (A. 37.)

Throat of a Fillet Weld. The shortest distance from the root of a fillet weld to its face.

Throat Opening. (See HORN SPACING.)

Through-Flow Process. A composite casting process, which consisted in causing a volume of the coating metal, much larger than that actually required for the coating, to flow through the mould, stopping the flow when bonding had developed. The process has not proved practical because of the excessively large volumes of molten coating alloy required. (S. 31.)

Throwing Power. In *electrodeposition*, the ability of a solution to give uniformity in thickness on a cathode of irregular shape, i.e. the power to deposit metal in recesses.

Thruray. An instrument for *ultrasonic* testing, using through transmission. The use of this instrument has been discontinued. (S. 77.)

Thrustorq. An instrument for measuring the comparative life of bearings; it employs compressed air to measure both torque and thrust. (S. 120.)

Thulium. (*Tm* or *Tu.*) *Atomic weight* 168·94. *Specific gravity* 9·35 (computed). An element belonging to the *erbium* family of the *rare earths*. Thulium 170 is a radioactive isotope used in gamma radiography, and for measuring the thickness of materials.

Thuriting. A heat treatment process in which the steel is heated rapidly to a temperature of about 925° C., followed by rapid cooling and *box annealing* at about 650° C. It is claimed that this treatment facilitates deep drawing operations.

Thwing Pyrometer. A radiation type of pyrometer in which the rays from the hot body are directed on to a conical mirror which concentrates them on to the hot junction of a thermocouple. The resulting electromotive force is read off on a millivolt metre, the dial of which indicates the corresponding temperature.

Thyssen-Bourdouxhe Apparatus. An apparatus for making corrosion tests in a slowly moving liquid medium on small specimens, 65 mm. long × 5 mm. in diameter; it has been used primarily for light metals and alloys, but also for cast iron. The specimen is contained in a horizontal wide-bore tube; the latter is connected at each end to a glass bottle, and these in turn are in connection with an inverted conical flask placed above them. The whole system is filled with the corroding solution, an air space being left above the liquid in the inverted flask. A water pump withdraws air from this air space and injects it into one of the tubes leading up to the inverted flask; acting on the principle of the air lift, the bubbles of air, rising in the tube, cause the whole of the liquid in the system to circulate slowly. The corrosion is measured by the loss of weight. (B. 25.)

Ti. Chemical symbol for *titanium*.

T.I.B. Abbreviation for *Technical Information Bureau*.

Tie Line. (See CONODE.)

Tie Piece. A bar or rod-shaped piece built into a *pattern*, and made a part of the casting to prevent the distortion caused by uneven contraction between separated members. (A. 26.)

Tie Rods. (*Ties.*) Rods used for holding together refractory sections.

Tie Weld. (See BRIDGE SPOT WELD.)

Ties. (See TIE RODS.)

Tig. An American abbreviation for *tungsten-inert-gas*.

Tigering. Increasing the speed of *sull-coating* by spraying with a weak solution of acid. The method, however, is liable to give an uneven coat.

Tight Coat. A galvanized or other metallic coating which is relatively complete and free from defects.

Tight Cooperage Hoop. A hoop specially designed for making watertight barrels.

Tight Flask. (See FLASK.) A *flask* with a rigid framework as opposed to a *snap flask*.

Tilt Hammer. An old type of hammer, driven by a water wheel. It consists of a wooden beam hinged at one end and with a hammer head at the other end. At an intermediate point along the beam, cams on a revolving shaft alternately raise the hammer end and allow it to drop upon an anvil. The term is now sometimes applied to small steam-operated hammers with a tup of up to 5 or 6 cwt.

Tilt Mould Ingot. An ingot made by a casting practice employing a *book-type mould* that has its bottom nearly vertical at the start of the pouring and is gradually tilted back to a normal horizontal position during pouring. The object of such a practice is to reduce the amount of agitation whilst the metal stream is being poured into the mould and thus to reduce the tendency towards formation of oxide film and entrapment. (See DURVILLE ROTARY PROCESS.) (A. 27.)

Tilting Furnace. A melting furnace that can be tilted to pour out the molten steel.

Tilting Open Hearth. A furnace mounted on a roller mechanism that tilts it forward or backward. There are two main types: *Campbell* and *Wellman*.

Tilting Table. A table used for holding metal before or after rolling. Either or both ends of the table can be raised or lowered to facilitate manipulation.

Time of Recovery. The time required, after a specified disturbance has taken place in an automatically regulated welding circuit, for the current and voltage to return to within a specified percentage of their original value. (B. 105.)

Time Quenching. (See INTERRUPTED QUENCHING.)

Time-Resistance. The capacity of a material to withstand a limited number of stress reversals above the fatigue strength until fracture supervenes.

Time Temperature Curve. A graph representing the cooling rate of a hot body.

Time Temperature Transformation Curve. (*TTT Curve.*) An *isothermal transformation curve* showing the time which austenite takes to transform isothermally at various temperatures between A_3 and the commencement of martensite formation (M_s). It is sometimes known as an *S-Curve*, so-called because for some steels, e.g. plain carbon steels, it represents a letter S in shape. The information given is useful in heat treatment practice, particularly for *interrupted quenching, martempering*, and *austempering*.

Time Test. In this test a pendulum, weighing 4 kg., is placed on the specimen, a hard sphere 1 mm. in diameter acting as pivot, and is caused to oscillate through a small arc. The time period of oscillation, taken with a stop-watch, is a measure of the size of the indentation, and thus of the hardness of the specimen. (See HERBERT PENDULUM HARDNESS TESTER.) (B. 39.)

Time Work-Hardening Test. (See HERBERT PENDULUM HARDNESS TESTER.)

Time Yield. (See HATFIELD TIME-YIELD.)

Timken OK Load. The maximum load which can be applied without failure of the lubricant, expressed in pounds per square inch. It reflects the wear occurring at this load. (K. 39.)

Timken Wear and Lubricant Testing Machine. A machine, in which a special type of cup revolves against a test piece and a lubricant is supplied at a predetermined rate and temperature. The test piece is mounted on a system of levers by virtue of which the test piece is always in the same relative position to the revolving cup and the unit load of the length of the cup and the test piece is always constant. This load can be set by sliding a weight along the friction lever. To determine the amount of wear, the weight of the test specimen is taken before and after the test. (M. 98.)

Tin. (*Sn.*) *Atomic weight* 118·7. *Specific gravity* 7·29. *Melting point* 231·9° C. A soft, lustrous metal having a white colour with a slightly yellow tinge. The principal ore of tin is *cassiterite*, also known as *Tin Ore, Tin Stone, Wood Tin, Toad's Eye*, consisting of tin oxide, SnO_2. *Stream tin* is tin ore in the state of sand as it occurs along the beds of streams or in the gravel of the adjoining region, which has been derived from the decomposition of rocks carrying tin ore. Tin has a low temperature of recrystallization and thus may be severely cold worked without intermediate annealing. Owing to its good resistance to corrosion in many conditions, the major use of tin is in the form of coatings for steel (see TINPLATE) and copper alloys. In hardened and tempered alloy steel it has been found that even 0·1% of tin has a detrimental effect on the notch impact value. In carbon steel this effect is not so marked in the oil quenched and tempered condition as in the normalized. The effect of tin in steel appears to be counteracted very appreciably by the presence of molybdenum. (B. 67.)

Tin Ash. Dross formed on the surface of a hot tinning bath by impurities.
Tin Bar. (See TINPLATE BAR.)
Tin Base Alloy. An alloy in which the chief component is tin.
Tin Cry. The peculiar crackling sound heard when pure tin is bent. It is assumed to be related to mechanical twinning of crystals. (A. 27.)
Tin Disease. (See TIN PEST.)
Tin Flower. The appearance of coarse spangles on galvanized sheet indicating the presence of tin and/or cadmium in the zinc bath.
Tin Nickel Alloy Plating. A coating, developed by the Tin Research Institute, consisting of two parts of tin and one part of nickel. It is hard and untarnishable and can be deposited bright in one operation. It has a good metallic lustre with a faint rose-pink colour.
Tin Ore. (See TIN.)
Tin Pest. (*Tin Disease.*) The tendency of tin, cooled to low temperatures, for example, about −50° C., to crumble into a powder known as *grey tin*, an allotropic modification.
Tin Pot. (See HOT TINNING.)
Tin Stone. (See TIN.)
Tin Sweat. The beads of tin-rich low-melting phase that are found on the surface of bronze castings when the molten metal contains appreciable amounts of hydrogen. (A. 27.)
Tin-Terne. *Terne* with a tin content approaching 25%.
Tinman's Solder. A tin-lead solder melting below a red heat, used for *tinning*. The most fusible solder contains 65% tin.
Tinned Wire. Wire which has been tinned after drawing to the required gauge.
Tinning. (*a*) The operation of coating with tin or sometimes with lead-tin solder. (See ELECTROLYTIC- and HOT-TINNING.) (*b*) Tinning is applied on those portions of surfaces of articles which it is desired shall not be hardened during the *nitriding* process.
Tinning Stack. Equipment for continuous *tinning*.
Tinplate. Mild steel with a protective coating of tin on each surface. It combines the strength of steel with the corrosion resistance of tin. The method of coating employs either *electrolytic-* or *hot-tinning*. (L. 23.)
Tinplate Bar. (*Tin Bar.*) Hot rolled steel of rectangular section intended for the production of *tinplate*.
TiO_2. Chemical formula for titanium oxide.
Tip Skid. (See ELECTRODE SKID.)
Tipper Test. This consists in breaking in a tensile machine a rectangular specimen having the full thickness of the material from which it is taken, and a width which should preferably be about twice the thickness. In each of the narrow faces (i.e. through the thickness) an *Izod* notch is cut, the two notches being opposite to each other. The loads at *yield* and at fracture are noted, as well as the *elongation* and *reduction* in thickness midway between the notches, and the character of the fracture. The tests are made at various controlled temperatures, and at the normal speed for tensile testing. This is not, therefore, an *impact test*. The most important indication of the test is the temperature range over which the character of the fracture changes from the tough *fibrous* type to the brittle *crystalline* type, i.e. the *transition temperature* for this test. The yield and *ultimate stresses*, the *elongation*, the *reduction in area* and the reduction in thickness are also significant. (T. 30.)
Tipping. The *brazing* or *welding* of hard alloy inserts (e.g. *sintered carbide* tips) on to carbon steel shanks; an economy measure to conserve the scarcer and more expensive materials.
Titan Process. A process of concentrating iron ore which comprises the steps of effecting a dry, thermal partial reduction of the iron in the ore to the metallic state to a degree of reduction of between 50% and 80%, subjecting the reduced product to a magnetic separation and recovering the magnetic concentrate. (T. 31.)
Titania. (*TiO_2.*) Titanium dioxide; it is used in the coatings of some welding electrodes.
Titanium. (*Ti.*) *Atomic weight* 47·9. *Specific gravity* 4·54. *Melting point* 1680° C. The pure metal is white, with a fracture like that of steel, which it generally resembles in physical properties. The two most important titanium minerals are *ilmenite* and *rutile*. For the production of *ferro-titanium*, ilmenite is generally preferred, whilst rutile is used in the manufacture of coated welding rods. Practically no oxidation of titanium occurs in the air up to a temperature of 120° C.; but when heated, a mixture of oxide and nitride results. When heated to 610° C. in oxygen, it burns with great brilliancy, titanium dioxide (TiO_2) being produced, and for this reason it is used in pyrotechnics. It is the only element which burns vigorously in nitrogen, and begins to burn at 800° C. to produce the nitride, TiN. However, it can be readily forged within the range of 850° to 980° C. and it is claimed that titanium and its alloys have excellent flow characteristics and yield excellent

die forgings. Titanium metal has recently attained considerable importance; it has been cast in 2-ton ingots and rolled into strip. In high carbon killed steels, ferro titanium is used as a final deoxidizer to prevent the occurrence of segregation and of objectionable inclusions and for controlling grain size. Apart from its deoxidizing properties, the effect of titanium on steel depends on the formation of an exceedingly stable carbide. In structural steel it may be added as a means of preventing the formation of *martensite* in the process of welding, whilst titanium is added to *austenitic stainless steels* to convert the carbon into a harmless form, and so prevent *intercrystalline corrosion* attack. In this respect it is probably the most active of the carbide-forming elements. The theoretical ratio of titanium to carbon required to form the carbide is 4 to 1. Further, it is used in steels for vitreous enamelling, where the addition of titanium in amounts of at least five times the carbon content prevents blistering in the enamel surface of the final product. A *hard metal*, titanium tungsten carbide, has been developed for use in tipping tools where it is claimed to give exceptional resistance to shock and *cratering*.

Titration. The volumetric determination of the strength of a solution of an acid, base, oxidizing or reducing agent by delivering from a burette an appropriate reagent of known strength using a suitable indicator where necessary, e.g the determination of manganese by reduction of the permanganate with a standard solution of ferrous ammonium sulphate until the disappearance of the colouration indicates complete reduction.

Titre. The standard of strength of a solution, as determined by *titration*.

Tl. Chemical symbol for *thallium*.

Tm. Chemical symbol for *thulium*.

T. Max. The maximum temperature for heating steel before quenching.

Tn. Chemical symbol for *thoron*.

Toad's Eye. (See TIN.)

Tocco Hardening Process. An *induction hardening* process, developed for use on crankshafts. It consists in passing a heavy low-voltage current (about 9000 amps. at 24 volts and at a frequency of 2250 cycles per second), through inductor blocks which surround the journal to be hardened, without actually touching it. High frequency alternating eddy currents are induced in the surface of the steel which is brought up to the quenching temperature in a few seconds, and is then immediately quenched by water, sprayed under pressure through holes drilled in the inductor blocks. (E. 48.)

Toe. The junction where the weld face adjoins the welded part.

Toe Crack. A crack in the *parent metal* occurring at the toe of a weld.

Toggle Cutter. A wire cutter.

Toledo Blade. (See DAMASCENE STEEL.)

Tolerance. The range between the upper and lower limits of a specification, e.g. as regards composition or dimensions; it is often expressed as plus or minus the specified quantity.

Tomlinson Recorder. A device by means of which the profile of the surface under test is traced on a smoked glass plate at a magnification of 100 ×. This record is then viewed or photographed with an optical magnification of 100 ×, giving a total of 10,000 ×. (L. 1.)

Tomlinson Strain Gauge. An instrument consisting of a U-shaped frame used to restrain the ends of a steel specimen consisting of two 6-in. wide strips which after placing in the frame are joined by a butt weld. The contraction taking place across the weld causes a deflection of the vertical members of the frame proportional to the total load introduced into the specimen by welding under exterior restraint. This deflection is measured by dial gauges and is proportional to the average stresses in the plate. (W. 15.)

Tomography. A division of *radiography* dealing with the photography of a particular plane in an object while leaving out undesired detail in other planes. Although this technique was developed for medical radiography, it is recommended for certain purposes in work with metals where it is essential that the location of faults be exactly known. (G. 47.)

Ton. The *long ton*, commonly used in Britain, is 2240 lb. The *short ton* used in Canada, South Africa, and the U.S.A. is 2000 lb. The *metric ton* or *tonne* (1000 kilograms), used in the Continent of Europe, is 2204·6 lb.

Tong Hold. (*Bar Hold.*) The end of a bar or forging which has been reduced in cross-section to enable it to be gripped by tongs for manipulation during forging.

Tonnage Oxygen. Medium purity oxygen gas generated on the consumer's works.

Tonne. (See TON.)

Tonpilz Machine. An apparatus for measuring *damping* values.

Tool. Any implement by means of which mechanical operations are performed. In *cutting tools*, a *right-hand tool*, when viewed looking on the point end of the tool with the face up, and the shank pointing away, cuts on the right-hand side of the tool point, whilst a *left-hand*

tool cuts on the left-hand side of the tool point. A *right bent tool*, when viewed in the same way, has the point bent to the right, and a *left bent tool* has the point bent to the left. A *right offset tool* has the point offset to the right side of the shank and usually parallel to the shank, and a *left offset tool* has the point offset to the left side of the shank and usually parallel to the shank.

Tool Steels. Steel characterized by hardness and toughness suitable for the production of tools. They usually contain from 0·5% to about 1·5% carbon and may have other additions such as tungsten, molybdenum, chromium, vanadium and cobalt. Plain carbon steels with up to about 0·9% carbon are used for such tools as drills and chisels, whilst files, saws and engraving tools may contain up to 1·5% carbon. Alloy additions are made to confer *red hardness*, *toughness*, and non-distorting properties. (See also HIGH SPEED STEELS, HARD METALS.)

Toolability. The ability of a sand to respond to hand tooling and patching.

Toolweld Process. A process in which electric *fusion welding* is used to build up the cutting edges on lathe tools, milling cutters, etc., which have become worn or damaged in use.

Top Blast Refining. A steel refining process in which pure oxygen is blown from above vertically, or almost vertically, at high pressure and high speed on to the bath through a nozzle, the end of the oxygen feed pipe being moved during the process in such a way that the oxygen is distributed as uniformly and widely as possible throughout the whole bath. Due to the uniform refining action thus obtained, local over-refining is prevented. (British Patent 700,224.)

Top Board. A wooden board used on the *cope* half of the *mould* to permit squeezing of the mould.

Top Casting. (*Top Pouring.*) *Teeming*, i.e. filling the ingot mould from the top with or without a *tundish*.

Top Hat. (See BOX HAT INGOTS.)

Top Pouring. (See TOP CASTING.)

Top Tackle. The name given to rolling mill equipment which assists the top guides to bear upon the top roll and thus prevent *collaring*. In most rolling mills the top tackle is a system of weights and chains or springs.

Topflight Hardness Tester. An automatic machine, which is preadjusted according to the thickness and minimum hardness required. Parts are then fed under the indenter. If the part is of the specified hardness, an electrically operated plunger marks it with the inspector's stamp, whilst a meter incorporated in the base of the machine counts the pieces within specification. The machine includes a specially adapted *Barcol unit* on which the range of hardness tested is between Brinell 33 and 155 (10 mm. ball—500 kg. load). The direct reading dial is divided in 100 graduations easily converted to *Rockwell*, *Brinell*, and *Vickers* numbers. (T. 42.)

Topochemistry. The study of reactions which occur only at certain definite regions in a system.

Topograph. An instrument for measuring surface finish which operates on a simple pneumatic principle and gives a pen record 10 in. long and 5 in. wide, on paper, in 3 min., the record being an enlarged profile of the surface irregularities along a selected straight line. On the graph traced by the pen the heights of the surface irregularities are directly ascertained in micro-inches by multiplication by the particular conversion factor for which the instrument is set. Irregularities of the order of 2 micro-inches are readily detected when the setting is for a magnification of 20,000 to 1. (E. 54.)

Topography. The term used in reference to metallic surfaces means the measurement of height and depth features. These details are of importance in machining, hardness testing, grain structure, etching, and surface wear.

Topping. Breaking off the *feeder head* from a small ingot, usually of tool steel, with the object of examining the fracture.

Torch. (See WELDING TORCH or CUTTING TORCH.)

Torch Brazing. A brazing process in which coalescence is produced by heating with a gas flame, using a nonferrous filler metal having a melting point above 430° C. but below that of the base metal. The filler metal is distributed in the joint by capillary attraction. (V. 4.)

Torch Hardening. (See FLAME HARDENING.)

Torch Tip. (See WELDING TIP or CUTTING NOZZLE.)

Torque. The turning moment exerted by a tangential force acting at a distance from the axis of rotation or twist. The product of the force and its perpendicular distance from the centre of rotation is a measure of the twinning moment or torque.

Torque Magnetometer. An instrument for the measurement of magnetic anisotropy in steel. The specimen, in the form of a disc, 1 in. in diameter and 0·01 to 0·10 in. thick, is rotated in a magnetic field, and the required *torque*

recorded automatically on a chart, the movement of which is proportional to the angle between the direction of rolling and that of the magnetic field. By the use of this instrument, desired anisotropy such as in transformer steel sheets, and undesirable anisotropy such as in steel sheet for deep drawing, may be detected. (S. 130.)

Torquemeter. An instrument constructed for accurate measurement of *torque* at high speeds—up to about 17,000 r.p.m. It consists essentially of a hollow steel shaft carrying a thin-walled steel sleeve tack welded to one end of the shaft. On the other end, the assembly carries two steel rings; one, with two mirror surfaces, is fastened to the torsion shaft, and the other, containing the third mirror surface, is mounted rigidly on the sleeve. A collimator with a light source is placed against the rings which are so oriented that the rays emitted are reflected by each mirror in turn and then return into the collimator where they are focused on the internal scale. Any twist of the torsion shaft does not affect the free end of the sleeve and thus a different reading on the collimator scale is registered. (R. 7.)

Torsator. An electric testing machine capable of applying alternating torsional stresses over a frequency range of 1200 to 3000 per minute. The machine can be used for testing complete crankshafts for motor-car or aeroplane engines, or for ordinary straight specimens. (E. 80.)

Torsion. The state of *strain* set up in a material by twisting.

Torsion Impact Test. A heavy flywheel equipped with two lugs is set in rotation at a high speed. The test piece is gripped tightly at one end, and on the other end there is clamped a cross arm. When the flywheel is up to a definite speed, a clutch is tripped and the lugs of the flywheel engage the cross arm on the end of the specimen producing a torsional blow violent enough to break the test piece. This slows down the flywheel and the tougher the specimen the more the flywheel is slowed down. All that is necessary is to note the speed of the flywheel just before and just after breaking the piece. The energy consumed in breaking the test piece may then be calculated.

Torsion Springs. Springs transmitting a twisting action instead of a direct push or pull.

Torsion Test. A measure of *ductility*, chiefly used for wire, in which one end of the test piece is gripped and the other twisted axially until fracture occurs. Although torsion test specimens are usually cylindrical, no standard dimensions have been established. When the test is carried out on wire, the length is related to the gauge, e.g. 100 diameters, and the number of twists to failure is recorded. When the test piece is taken from a bar it is usual to report the *maximum stress* in shear and the angle of rotation. Full-size parts are frequently tested.

Torsion Testing Machines. (*Avery Torsion Testing Machines.*) (*a*) A motor-driven machine, consisting of two units, a straining unit, which applies the load at one end of the test body, and a weighing unit, which measures the reaction at the other end. A protractor graduated from 0 to 360 degrees is fitted to the straining shaft and readings of the angle of twist to 0·1 degree are obtained by means of a *vernier*. The *torque* is automatically indicated by a pointer on the chart of the weighing unit, which is graduated from 0 to 175,000 in. lb. divisions. (*b*) A hand-operated machine, designed to test in torsion when the deflection under load is small. It consists generally of a cast iron bed, on which is mounted a pedestal carrying the torque arm, and a fixed headstock carrying the straining gear. The load indicator comprises a torque arm and a lever system, through which the load is transmitted to be indicated by a pointer upon a dial, having two sets of graduations, or it may be shown on a *steelyard*.

Torsional Fatigue Machine. A *fatigue* machine with controlled *torque*, in which the maximum torque in a completely reversed torque cycle is electronically controlled to $\pm$ 2% or better. The machine is of the resonance type, being a freely suspended two-mass system, with the specimen—usually a one-throw crank as the flexible element, maintained in torsional oscillation by a rotating out-of-balance mass which is driven by an electric motor through a flexible coupling. The machine is run near resonance, control of torque being then exercised by control motor speed. This is done electronically, as is the measurement of torque, using a capacity-type gauge. On failure of the test specimen, or of the machine itself, the machine stops automatically. (P. 14.)

Torsional Oscillation Method. A method of measuring the *damping* capacity of wire specimens. In one form, a horizontal thin rod of wood, carrying weights at each end, is attached at its midpoint to the middle of the vertical wire specimen, attached above

and below to pulleys so that it can be stressed as desired while keeping the experimental length constant. The time required to reduce the amplitude of the oscillations of the rod to half the original value is measured and the damping capacity is then calculated by a simple formula. (S. 4.) In another form the specimen is vibrated between two electric magnets and the deflection is recorded optically by the reflections of a beam of light from two mirrors. (H. 29.)

Torsional Strength. The *maximum shear stress* which a material will withstand on twisting.

Torsionmeter. A machine for applying torsion fatigue tests to test pieces of up to 0·9 in. diam. and 6 in. long, operating at a speed of 1500 r.p.m. The *torque* applied to the specimen is transmitted through the torsionmeter and is measured by the movement of a spot of light reflected from a mirror on to a photographic plate. (H. 66.)

Tossing. The purification of tin by slowly pouring from one ladle into another, so as to expose the liquid metal to the air, oxidizing the impurities and forming dross which can then be removed.

Total Carbon. The total content of carbon in cast iron, including free carbon, present as *graphite*, and *combined carbon*, chemically combined with the iron or alloying constituents as carbides.

Total Radiation Pyrometer. This consists of a thermojunction in a cylindrical tube. A set of two or more diaphragms limits the cone of vision from the source of radiation and the thermojunction is placed at the apex of this cone. A given temperature will raise the temperature of the thermojunction to a point of equilibrium, determined by the surroundings. Thus, the *e.m.f.* of the thermojunction can be calibrated for a range of temperatures. (H. 34.)

Total Reduction. (See REDUCTION.)

Total Strain Method Using Dividers. (See YIELD POINT.)

Tote Box. An American term for a metal container used to handle small castings or forgings, or the like, through the various operations.

Touch Welding. A form of *spot welding*. The sheets to be welded are laid in good contact and a small area of the upper sheet is melted. The penetration is sufficient to fuse it to the one below. By this means, steel covering sheets may be attached to angles and sections, and the process is particularly adapted for shipyard work.

Touch-Up Granodine. A zinc phosphate protective coating, used for anchoring paint to cold-rolled steel. It can be applied by hand.

Tough Fracture. (See FRACTURE.)

Toughener. A term for an alloying element added for the purpose of increasing the strength of steel.

Toughening. The process of *tempering* steels at a relatively high temperature after quenching in oil or water from the normal hardening temperature.

Toughness. (*a*) A characteristic of combined strength and ductility which enables a material to resist fracture by shock, bending or twisting. It is associated with high values in the *notched bar impact test*. (*b*) The term as applied to *moulding sand* describes its capacity to withstand pressure and movement during the stripping of the pattern or lifting of the mould.

Tour-Marshall Test. (*Stiffness Test.*) A test in which a machine operates on the cantilever-bend principle. Cantilever bending of the specimen is obtained by rotating a vice in a counter-clockwise direction, pressing the free end of the specimen against the underside of the roller pin which projects from the dial face. This dial is part of the pendulum, which is free to swing on ball-bearings concentric with the rotating vice. Different capacity ranges are obtained by placing different weights on the pendulum pin. Engraved on the dial face is the angular deflection scale, reading from 0 to 90 degrees. (M. 2.)

Towers Magnetic Stirrer. A device utilizing a rotating field of magnetic force to induce a vigorous rotary movement in a small magnetized bar totally enclosed in a polythene or glass tube, and placed in the liquid to be stirred. (L. 1.)

Trace. An extremely small quantity of an element, usually too small to determine quantitatively.

Tracer Element. (See RADIOACTIVE ISOTOPES.)

Trade Associations. (See Appendix V.)

Trade Commissioner Service, Board of Trade. Horse Guards Avenue, London, S.W.1.

Trade Enquiry Office, Board of Trade, Commercial Relations and Exports Department, Horse Guards Avenue, London, S.W.1.

Trade Heat Method. (See MONELL PROCESS.)

Trade Mark. A registered device or name, marked upon or displayed in connection with an article for sale, the device or name being peculiar to and the sole property of the producer or manufacturer of the article. Application for the registration of trade marks in the United Kingdom should be ad-

dressed to the Patent Office (Trade Marks Branch), 25 Southampton Buildings, Chancery Lane, London, W.C.2. In the United Kingdom, trade marks are granted for seven years, renewable for fourteen years and every fourteen years thereafter. A trade mark costs 20*s.* stamp duty on application; 40*s.* registration after acceptance; and 40*s.* for each renewal.

Tramlines. (*a*) An *overfill* appearing as two parallel lines on rolled bars. (*b*) Long straight marks due to drawn out inclusions on rolled sheet.

Tramp Element. (See INCIDENTAL ELEMENT.)

Transcrystalline. Literally, across the crystal. (Cf. INTERCRYSTALLINE.)

Transcrystalline Fracture. Failure in metals caused by fracture occurring through the crystals themselves and not along the crystal boundaries as in *intercrystalline fracture*.

Transfer Ladle. A ladle used to transfer metal from one furnace to another.

Transformation Range. (*Transformation Temperature Range.*) The temperature interval within which austenite forms while ferrous alloys are being heated. Also the temperature interval within which the austenite transforms while ferrous alloys are being cooled. The range on cooling is lower than the corresponding range on heating; this phenomenon is known as *thermal hysteresis*. The limiting temperature of the ranges depends on the composition of the alloy and on the rate of change of temperature, particularly during cooling. (See also IRON-IRON CARBIDE DIAGRAM and TRANSFORMATION TEMPERATURE.)

Transformation Temperature. The temperature at which a change in phase occurs. The term is sometimes used to denote the limiting temperature of a *transformation range*. In order to distinguish between the *critical points* on heating and on cooling, those on heating are known as the Ac points (c = chauffage or heating) and those on cooling as the Ar points (r = refroidissement or cooling). The following symbols are used for iron and steel:

Ac_{cm}. In *hyper-eutectoid* steel, the temperature at which the solution of cementite in austenite is completed during heating.

Ac_1. The temperature at which austenite begins to form during heating.

Ac_2. The temperature at which iron becomes non-magnetic on heating. (See MAGNETIC CHANGE.)

Ac_3. The temperature at which transformation of ferrite to austenite is completed during heating.

Ac_4. The temperature at which austenite transforms to delta ferrite during heating.

Ae_1, Ae_3, Ae_{cm}, Ae_4. The temperature of phase changes at equilibrium, e.g. Ae_1 is defined as the equilibrium temperature dividing austenite and ferrite from ferrite and cementite, whilst Ae_3 is the equilibrium temperature dividing austenite from austenite and ferrite.

Ar_{cm}. In *hyper-eutectoid* steel, the temperature at which precipitation of cementite starts during cooling.

Ar_1. The temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.

Ar_2. The temperature at which iron becomes magnetic on cooling. (See MAGNETIC CHANGE.)

Ar_3. The temperature at which austenite begins to transform to ferrite during cooling.

Ar_4. The temperature at which delta ferrite transforms to austenite during cooling.

M_s. (or Ar''). The temperature at which transformation of austenite to martensite starts during cooling.

M_f. The temperature at which martensite formation finishes during cooling.

All the critical points occur at lower temperatures during cooling than during heating, and depend on the rate of change of temperature. (See also IRON-IRON CARBIDE DIAGRAM and TRANSFORMATION RANGE.)

Transformation Temperature Range. (See TRANSFORMATION RANGE.)

Transformer Iron. (See TRANSFORMER SHEETS.)

Transformer Sheets. Sheets intended for use in electrical apparatus, e.g. transformer cores. Such sheets are rolled from *transformer iron* which contains less than 0·015% carbon and about 4% silicon. (See SILICON.) (H. 22.)

Transite. A composite material made of asbestos fibre and Portland cement moulded under high pressure. It is used in the foundry in the form of plates for holding cores, etc., during drying operations.

Transition Element. An element occurring in the triads of group VIII of the *Periodic Table*; an element whose two outermost electronic groups, or energy levels, are imperfect, i.e. not containing 8 or 18 electrons, e.g. iron, platinum, rhodium.

Transition Lattice. An intermediate, unstable crystallographic configuration, that forms during solid metal reactions, such as precipitation from solid solu-

tion and eutectoid decomposition. (A. 27.)

Transition Point. The temperature at which the crystalline form of a certain substance is converted into another solid modification of it, i.e. the temperature at which both forms can exist in equilibrium.

Transition Products. Products resulting from the transformation of an original constituent, the rate of cooling deciding which one or more of a series of various decomposition products shall result. Thus, *austenite* is transformed in cooling through the *critical range*, into one or more of various transition products, *martensite*, *troostite*, *sorbitic pearlite*, etc., the rate of cooling deciding which of these will be formed. (See also CRITICAL COOLING RATE.) (Plate VIII.)

Transition Temperature. The temperature at which the change from tough to brittle fracture occurs in a *notched bar impact* test, or sometimes in other forms of test, e.g. *notched tensile test*.

Transmission Method. (For X-ray or crystal analysis.) Having the diffracted *X-rays* emergent from a surface that does not face the source. (A. 27.)

Transmutation of Elements. A term used by the alchemists to signify the change of one metal into another, e.g. lead into gold, and subsequently held to be impossible; with the present knowledge of *radioactivity* and *atomic structure* it is seen that the process goes on continuously in radioactive elements. It has also been possible in recent years to carry out artificial transmutation. Thus, for example, magnesium has been turned into aluminium, and then again into silicon.

Transparent Reflector. A disc of thin plain glass placed at an angle of 45° across the axis of a microscope directly opposite an aperture in the side of the tube. It is used for the examination of metals under normal or vertical illumination.

Transverse. Literally "across", signifying a plane at right angles to the direction of working.

Transverse Seam Welding. (*Circular Seam Welding, Circumferential Seam Welding.*) The making of a seam weld in a direction essentially at right angles to the throat depth of a seam welding machine. (A. 37.)

Transverse Strength. (*a*) In wrought steel, the mechanical properties attained in the transverse direction are usually different from those attained in the longitudinal direction, e.g. the value for elongation will be greater when the stress is applied to the steel in a direction parallel to the rolling or forging than when the force is applied in the transverse direction. (*b*) The transverse modulus of rupture of a sand mixture. (*c*) The strength of a cast iron bar under the *transverse test*.

Transverse Test. A standard test applied to cast iron for the determination of the transverse or bending strength. The test bar when placed on supports set at a specified distance apart, which varies with the size of bar, is required to sustain a predetermined minimum load applied at the centre of the bar, and to give a specified minimum deflection before fracture.

Trap Weld. A development of *cold welding* in which the fabricated metal form has a metal insert firmly embedded into another metal structure by pressure alone without the application of heat. (D. 46.)

Trauwood Process. A process for *patenting*, *tempering* or *annealing* steel rod or wire, by passing an electric current through its cross-section. The advantages claimed include higher and more uniform physical and fatigue properties, whilst surface decarburization and scaling are generally negligible.

Treated Steel. A term used in *S.A.E.* specifications to denote that a steel has received special additions such as ferroboron or other boron alloy. The letter T is inserted between the first and second pair of digits, e.g. S.A.E. 13T30.

Tree Wire. Copper wire for use in overhead cables, etc., containing 0·9% cadmium. It is claimed that this addition gives substantially increased strength, with only about 10% reduction in conductivity.

Trentini Surface Tester. A Swiss instrument in which surface finish or roughness is measured by producing shocks in an electrical system. These shocks are produced by drawing a needle with a blunt point across the surface at constant velocity and under constant load, the magnitude of the impulses being proportional to the roughness of the measured surface. (I. 5.)

Trepan. A hollow tool used in *trepanning*.

Trepanning. The process of boring reasonably large holes by cutting a cylindrical groove and removing the centre as a solid core instead of removing all the metal within the bore in the form of chips. Accurate results can be obtained by the use of this method of producing deep holes such as the bores of gun barrels. (M. 60.)

Trepanning Head. The end of the trepanning machine in which the cutting tools are inserted and which carries out

the cutting operation. The head is fluted on the outside to allow the cuttings to be washed away by a coolant pumped through the head.

Triad. (*a*) A group of three elements, with similar characteristics, such as iron, cobalt and nickel in group VIII of the *Periodic Table*. (*b*) A term, now obsolete, for a *trivalent* element.

Tribasic. An acid containing three replaceable hydrogen atoms in a *molecule*.

Tribocouple. Two chemically dissimilar metals in mutual electrical contact. The friction produced by the mechanical agitation of the two members of the couple results in the flow of an electric current. The power of a tribocouple is the magnitude of the current which it will generate under specified conditions of friction.

Triboelectric. Electrifiable by friction.

Triboelectric Effect. The electric current produced by a *tribocouple*.

Triboelectric Sorting. The *triboelectric effect* has been applied for the purpose of identifying and sorting mixed materials. The actual construction of a triboelectric sorting instrument, known commercially as the *Metalsorter*, combines a control unit cabinet which contains the galvanometer assembly and several circuit elements necessary to the operation of the instrument. The mechanism and controls for creating the reciprocating motion of the movable member of the *tribocouple* is known as the *tribosorter* and is attached to the control cabinet by means of a multi-conductor cable and removable plug. The tribosorter head and accessory fixtures are stored and carried conveniently in the control unit compartment. A test-rod, about 3 in. long by ¼ in. in diameter, is fastened into the nose of the tribosorting head, between the two contact rods. The sorting head is held against the sample so that the contact rods and the test rod bridge the sample simultaneously, thereby completing the circuit. Stray thermo-electromotive forces are balanced before a test is made by rotation of the circuit balancing knob, until the galvanometer reads zero. The testing initiating switch is then closed and the test-rod will reciprocate across the sample at a periodicity of 20 strokes in 2 seconds. If the test-rod and the sample form a tribocouple, the galvanometer indicator will be seen to move towards some positive or negative value and its maximum reading is taken as the measure of the triboelectric output power. A non-destructive thermoelectric test for sorting mixed analyses is called a *thermosorter* and is contrived so that it is attachable to the Metalsorter control unit in place of the tribosorter head. Its circuitry is designed to interlock with the Metalsorter control cabinet circuits. Virtually the same operating instructions apply to both instruments except for the placement of the reference standard. The thermosorter applies a thermoelectric test to the sample by utilizing the sample as one leg of a thermocouple while the reference standard, in the form of a short length of wire, forms the conjugate leg. A temperature gradient is produced by a resistance heated electrode at the hot junction of the thermocouple and the cold junction is formed simultaneously with the application of the test by spring-loaded contact rod. (D. 44.)

Tribophysics. The physics of *friction*.

Tribosorter. (See TRIBOELECTRIC SORTING.)

Triclorethylene Solvents. Solvents used for the degreasing of steel. They may be applied by immersion of the part, or by vapour or spraying. (H. 59.)

Trickle Scale. (*Tail Scale.*) Scale which has become detached from a pack of sheets in pack rolling, trickling in between the pack and becoming embedded in the surface of the sheets during further rolling.

Triclinic System. A crystallographic system which refers to crystals with three unequal axes, which are not at right angles.

Tridymite. (SiO_2.) A form of pure silica produced during heat treatment in a kiln. It is stable from 870° to 1470° C.

Trillion. British 10^{18}, i.e. a million million million; in the U.S.A. 10^{12} i.e. a million million.

Trim. To remove the flash or excess metal from a forging by a shearing operation. This may be done hot or cold.

Trimmers. *Trimming dies.*

Trimming. Removing *fins* and *gates* from hard iron castings by means of hand hammers.

Trimming Dies. *Dies* used to remove surplus metal in the form of *flash* produced at the *parting line* in *drop forging*. Trimmer dies are usually made in two or more sections, depending on the type of forging to be trimmed. (M. 174.)

Trimming Shoe. The tool used to hold the *trimming dies*.

Trimorphous. (See POLYMORPHISM.)

Trip Hammer. (*Helve Hammer.*) An old type of hammer in which along the circumference of an oak shaft, bearing a water-driven paddle wheel on its

outer end, there are rows of iron pegs, which, as the shaft rotates, press down the ends of the hammer shaft.

Triplexing. A method of steelmaking which involves the use of three processes, e.g. a sequence of melting in a *cupola*, blowing in a *Bessemer converter* and finishing in a *basic* electric furnace, or a combination of the acid *Bessemer converter*, the *basic open hearth-* and the *basic electric-furnace*.

Tripoli. A porous siliceous earth, resulting from the natural decomposition of siliceous sandstone, used as an abrasive polishing powder, and filtering material, etc.

Tripolite. (See INFUSORIAL EARTH.)

Trittium. An isotope of hydrogen, having an atomic weight of 3. (See HEAVY HYDROGEN.)

Triturating. Grinding to a powder under substantially dry conditions.

Trivalent. Having a *valency* of three.

Trommel. A revolving, cylindrical screen used in grading coarsely crushed ores. (A. 27.)

Troostite. A lamellar aggregate of *ferrite* and *cementite* in so finely divided a form that it is on the limits of resolution of the optical microscope. It etches rapidly and is black or dark brown in colour. There is no universally accepted definition based on the mode of formation, the modern tendency being either to avoid the use of the term or to restrict it to the initial product of the tempering of *martensite*.

Troosto-Martensite. A constituent obtained in the tempering of *austenite* with a structure and properties intermediate between those of *martensite* and *troostite*.

Troosto-Sorbite. A constituent obtained in the tempering of *austenite*, with structure and properties intermediate between those of *troostite* and *sorbite*.

Tropenas Converter. A small, tilting, *side-blown converter* with two rows of *tuyeres* on one side. The lower set directs the blast on to the surface of the metal, and the upper set supplies air for burning the carbon monoxide to carbon dioxide, thereby getting a greater heat efficiency. (See also ELECTRIC TROPENAS FURNACE.)

Trough. (See TUNDISH.)

Trough Casting. (See TUNDISH CASTING.)

Trowel. A tool used for slicking, patching and finishing a mould.

Troy Weight. (See Appendix II.)

True Arc Voltage. In *welding*, the sum of the *arc-stream voltage*, the *cathode drop*, and the *anode drop*.

True Centrispinning. (See CENTRISPINNING.)

True Freezing Point. The highest temperature at which crystallization can take place. (Cf. LABILE RANGE.)

True Steel. A term used by the late Professor J. O. Arnold for *eutectoid* steels containing 100% *pearlite*.

True Strain. A value found by referring the extension at any instant to the actual length at that instant, instead of to the original length.

Trueline Binder. A synthetic resinous material used as a *core binder*.

Trumpet. A refractory lined tube used in *uphill casting*.

Try Hole. A small hole in the top of the *blast furnace* through which the *stock indicator* passes.

Tschernoff, Dimitri. (1839–1921.) Born in St. Petersburg, Dimitri Tschernoff carried out classical researches on the growth of *dendrites* and on the influence of heat treatment on the structure and properties of steel.

t.s.i. Tons per square inch.

TTT Curve. An abbreviation of *Time Temperature Transformation Curve*.

Tu. An alternative chemical symbol for *thulium*.

Tube Reducer. A machine in which a pair of rolls is used for cold rolling tubing and rod. These rolls have a tapered groove around part of their surface, corresponding to the intended change in outside dimension of the tube or rod. The stock is rotated between working strokes. This process is somewhat different from the *Pilger Process* in that the stock moves in the same direction, as rolling proceeds; the axes of the rolls move back and forth parallel to the stock, and the direction of rotation of the rolls changes between the forward working stroke and the backward return stroke. A fixed mandrel is used in rolling tubing. (A. 27.)

Tuberculation. A form of corrosion in which the products of corrosion appear in the form of blisters or nodules.

Tucking. Pressing sand with the fingers under *flask bars*, round *gaggers*, and other places where the *rammer* does not give the required density. (A. 26.)

Tukon Tester. An instrument for the determination of *micro-hardness*. It is completely automatic under electronic control in a synchronous circle. The indentation is made by elevating the specimen against the indenter until the hardness of the specimen resists further indentation. As this condition is reached, an electronically controlled circuit prevents further elevation of the specimen and the load is applied for 20 seconds. The instrument is made in three models, to cover the entire range of diamond pyramid testing, i.e. with both the *Knoop* and 136 degree *Diamond Pyramid*

Indenters, and applies loads of from 10 grams to 50,000 grams.

Tumbling. (*Rumbling.*) An operation in which the work (usually castings or forgings) is rotated in a barrel, drum or chest together with metal stars or slugs, and/or various abrasives, such as pumice, slag, granite chips, sand, etc. The function of tumbling is analogous to grinding. It removes sand, skin, scale and fins from castings and scale from forgings. It cleans to a uniformly smooth surface, ready for machining and other operations. Tumbling removes a considerable amount of metal and dimensional changes in the work are relatively large. (M. 143.) *Blast Tumbling* is a modification of normal tumbling. The articles to be cleaned are charged into a *tumbling barrel*, which is so made that air blast can be directed through one or both ends, the jet or jets being arranged at an angle which ensures the greatest possible area being covered. As the barrel slowly revolves, the articles inside tumble over each other, bringing new faces under the action of the blast. The slow speed of this action, however, keeps breakages to a minimum.

Tumbling Barrels. (*Rolling Barrels, Rattlers.*) Rotating barrels in which castings and other parts are cleaned. (See TUMBLING.)

Tundish. (*Bakie.*) (*Trough.*) A refractory lined vessel which may be interposed between the *ladle* and the *ingot mould* in *teeming*. The dish is provided with a number of holes through which the metal enters the moulds thus minimizing splash and modifying the rate of pouring.

Tundish Casting. (*Trough Casting.*) Top casting with the use of a *tundish*.

Tungsten. (*W.*) (*Wolfram.*) *Atomic weight* 183·92. *Specific gravity* 19·3. *Melting point* 3380° C. The two most important commercial ores of tungsten are *wolframite* and *scheelite*. Owing to its high melting point, there is no refractory suitable for containing molten tungsten. *Powder metallurgy* methods, therefore, are used to consolidate tungsten powder into bars suitable for hot working to sheet, wire or other useful shapes. Although normally non-ductile in character, it has been found that when tungsten is heated it undergoes remarkable molecular changes and, in fact, becomes so ductile that it may be easily worked while hot and hammered into bars, rolled into sheets, or drawn through dies into wires, and after a certain amount of working, takes up such physical or molecular structure or characteristics as will mechanical working at room temperatures. Tungsten oxidizes in air only at a red heat and is highly resistant to the attack of the usual mineral acids. The electrical conductivity of tungsten is very good, and it is used for filaments in electric light bulbs, non-consumable welding electrodes, in tungsten arc lamps, in radio valves, for magneto and other contacts in the form of alloys with copper and nickel, and, by reason of its low *thermal expansion*, for leading-in wires through borosilicate glass. Tungsten strengthens steel at normal and elevated temperatures. Owing to the hardness of the carbide and its influence on secondary hardening, it is almost indispensable in high-speed tool steels, molybdenum being its only substitute. A very high temperature, approaching the melting point, is necessary to bring the carbide into solution for hardening. In addition to its use in high-speed steels, tungsten finds considerable application in general tool steels, die and precipitation hardening steels, and in stellite. In magnet steels it is used in amounts up to 6% and it has found a useful application in various creep-resistant steels, also in valves and other steels required for use at high temperatures. Tungsten is an essential constituent in the sintered *hard metals*.

Tungsten Carbides. Two phases occur in tungsten-carbon alloys corresponding to the formula W_2C and WC. It is the latter carbide which forms the major constituent of *hard metals*.

Tungsten Electrode. A non-filler non-consumable welding electrode, consisting of tungsten wire.

Tup. (*a*) The striking face of a steam hammer. (*b*) The striking weight in a *drop test*.

Turanite. ($5CuO.V_2O_5.2H_2O$.) A vanadium ore.

Turbidimeter. An instrument for the determination of matter existing as suspended particles in a liquid.

Turbo Hearth. A basic lined, partly closed, *side-blown converter* used to produce *Bessemer steel* with a nitrogen content comparable with that of *open hearth steel*. (B. 7.)

Turbulence Cushion. The term as used in the foundry refers to the extension of a *downgate* in the *mould*, below the level of the *crossgate*. This forms a well which contains the initial turbulent metal and acts as a cushion for the remainder of the pour in casting.

Turgite. (*Hydrohaematite.*) A hydrated iron ore ($2Fe_2O_3.H_2O$).

Turk's-Head Rolls. Four undriven working rolls arranged in a square

that serves as a die for drawing strip or wire to a rectangular section. (A. 27.)

Turnbull Casting Process. In this process, molten metal is poured through a feeder head into a mould, extraneous heat being applied to the mould prior to pouring of the molten metal by igniting a thermo-alumino mixture contained in recesses which are so disposed as to set up a temperature gradient in the metal when poured, thus causing solidification of the metal to commence at the end of the cavity remote from the feeder head and to extend progressively towards the feeder head. (T. 51.)

Turnbull's Blue. Ferrous ferricyanide. (Cf. PRUSSIAN BLUE.)

Turner Impact Test. A test to determine the resistance to bending or fracture of a material in which a hammer is allowed to fall from a predetermined height on to the specimen under test.

Turner's Sclerometer. A hardness tester employing a diamond point which is loaded until its movement over the surface of the test specimen produces a scratch of standard depth.

Turning. (*a*) A method of producing a cylindrical part by bringing the cutting edge of a tool against it whilst the part is rotated in a lathe and so removing a predetermined depth of surface. (*b*) The material removed in the turning operation.

Turn-Pin Test. (See DRIFT TEST.)

Tutenag. (*a*) In India, the name for zinc. (*b*) A nickel silver alloy containing about 45% copper, the balance being nickel and zinc in widely varying proportions.

Tuyere. (*Twyer.*) A nozzle through which air is blown into a *Bessemer converter*, *blast furnace* or *cupola*. It is usually made of copper and kept cool by circulating water. The term may be applied to nozzles through which air is blown into other types of furnaces. (See Figs. 1, 2 and 4.)

Tuyere Cap. The gas-tight closure of the small opening or *wicket* provided at the bottom of the *tuyere stock* to allow for the insertion of a thin rod to clean out the tuyere without removing the blow-pipe.

Tuyere Ratio. The ratio of the *tuyere* area to the combustion area. (A. 26.)

Tuyere Stock. (*Penstock.*) A refractory lined pipe through which the hot blast of a *blast furnace* passes. It is situated between the *goose neck* and the *blow-pipe*.

Tuyere Zone. That part of the *cupola* in the region of the *tuyeres* where combustion takes place.

°Tw. (See TWADDELL HYDROMETER.)

Twaddell Hydrometer. This type of hydrometer is supplied in sets of six to cover the range of specific gravities from 1·00 to 1·85. Water is taken as 0° Tw, and the scale is so arranged that each ° Tw = 0·005 specific gravity. To convert ° Tw to specific gravity, divide by 200, and add 1·000; to convert specific gravity to ° Tw, subtract 1·000 and multiply by 200. Twaddell hydrometers are always used for densities greater than water.

Twin-Arc Welding Process. The use of two small diameter electrodes in place of one larger electrode in a single submerged arc welding head. The deposition rate is faster than with the single arc process, time savings of up to 50% having been obtained. (W. 20.)

Twin Bands. (See *Twinning*.)

Twin-Carbon Arc Brazing. A brazing process wherein coalescence is produced by heating with an electric arc maintained between two carbon electrodes and by using a non-ferrous filler metal, having a melting point above 430° C. but below that of the base metals. The filler metal is distributed in the joint by capillary attraction. (A. 37.)

Twin-Carbon Arc Welding. An *arc-welding* process wherein coalescence is produced by heating with an electric arc maintained between two carbon electrodes and no shielding is used. Pressure is not used and filler metal may or may not be used. (A. 37.)

Twinned Crystals. Two individual crystals united symmetrically about a plane which is a possible face of the crystals of the substance or about an axis which is a possible crystal edge. In metal sections, *twinning* is evidenced, by the presence of twinning bands of different but uniform orientation forming parallel systems.

Twinning. (*Annealing Twin Bands.*) Well-defined bands in crystals in which the orientation of the atoms in the crystal lattice is the mirror image of that of the remainder of the crystals. It is definite evidence of heat-treatment following cold-work, as in the austenitic 18/8 stainless steels. (See Plate IX(d).)

Twist. (*a*) A condition wherein the ends of a rolled bar have been forced to rotate in relatively opposite directions about its longitudinal axis. It may be caused by excessive draft, faulty setting of delivery guides, or lack of uniform temperature in the bar. (*b*) (See FLASH).

Twist Drill. A steel drill in which cutting edges of specific *rake* are formed by

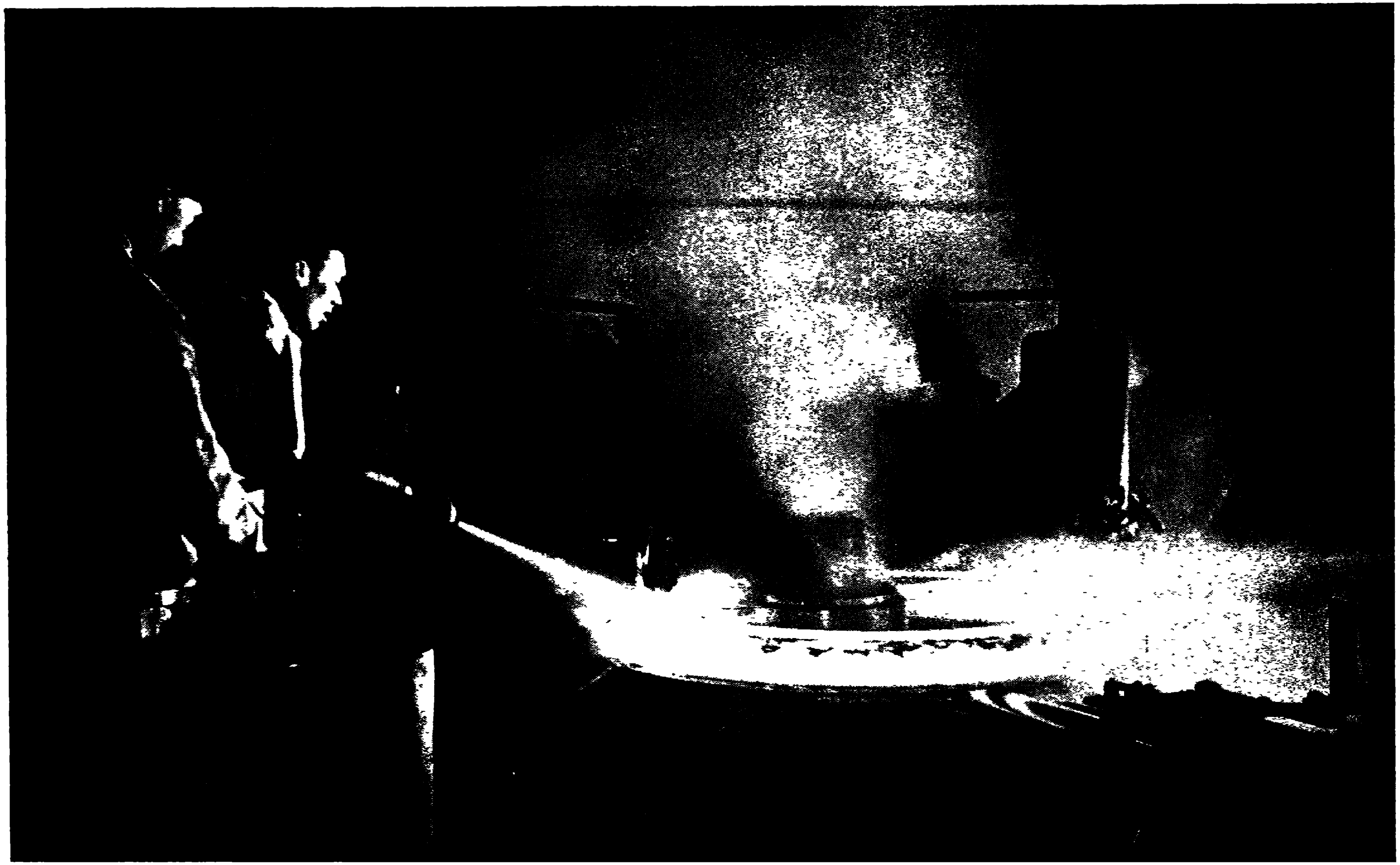


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Plate XVI.—Tyre rolling.

the intersections of helical flutes with the conical point, which is backed off to give clearance.

Twist Guide. (See GUIDES.)

Twisted Strip. Strip in which the edges are longer than the middle, thus causing distortion.

Two Colour Optical Pyrometer. The instrument comprises a lens system, disappearing filament lamp, battery, *rheostat* and ammeter as found in the usual optical pyrometer. There is, in addition, a graduated neutral wedge and a special filter consisting of two half circles of contrasting colours which meet across a diameter to form a sharp separating edge. In operation, the neutral wedge and the current adjusting rheostat are moved in quick succession until the filament disappears simultaneously through both halves of the filter. Two or three operations are all that is usually necessary. The temperature of the object is then read off the ammeter which is appropriately calibrated, whilst the position of the neutral wedge depends on the emissivity of the object, a scale of which may be associated with the wedge. Once the latter has been set for a certain object all subsequent adjustments for measuring the temperature for this object under similar conditions are carried out only by means of the rheostat. A red/green combination is usual but a red/blue filter may also be incorporated for greater sensitivity. (J. 5.)

Two High Mill. (See ROLLING MILLS.)

Two-Minute Wire. An American term for galvanized wire which will withstand immersion in a neutral copper sulphate solution for two minutes.

Twyer. An alternative spelling of *tuyere*.

Type. (*a*) In *drop forging*, a hardened block machined to the shape of a portion of the required forging and tapped in that part of the die impression to determine its shape. (*b*) In printing, see POINT.

Type Metal. A series of alloys containing 54% to 95% lead, 2% to 28% antimony and 2% to 20% tin, used to make printing type. Such alloys give particularly sharp impressions of their moulds due to their characteristic property, conferred by the *antimony* content, of expanding slightly on solidification.

Type Number. A designation provided by the American Iron and Steel Institute for each of the standard grades, i.e.—analyses.

Tyre. In general, the term relates to a ring of metal or rubber placed round a wheel to increase the strength, and to reduce wear and jarring. A locomotive tyre consists of a forged steel flanged ring which is fastened on to the rim of the cast steel wheel centre. This tyre being renewable gives prolonged life to the wheel and increased strength.

Tyre Rolling. The process of rolling a hot blank in the shape of a thick walled ring with a relatively small internal hole which has been produced by *becking* a punched *cheese* of steel. This ring is squeezed between an inner roll, which passes through the central hole, and a larger, external roll, the ratio of the diameters of the rolls being approximately 1 to 2·5. Rolling is continued until the internal and external diameters are comparatively large and the cross-section of the ring has been reduced and shaped to the form of the flanged tyre. (See Plate XVI.) (I. 73.)

Tyre Steel. Carbon steels for rail and tramway tyres may contain from 0·48% to 0·65% carbon with about 0·25% silicon and 0·70% manganese. In the carbon-chromium steels the silicon and manganese remain at about 0·25% to 0·70% respectively and carbon ranges from about 0·52% to 0·72%, and there is about 0·45% of chromium. Another tyre steel contains approximately 0·36% carbon, 0·25% silicon, 1·25% manganese, 0·70% chromium and 0·45% molybdenum. (See BRITISH STANDARD 24, Part 2: 1942.)

Tysland-Hole Furnace. A low shaft electric smelting furnace developed in Norway. It is of considerable importance in countries where coke is expensive and hydroelectric power is available, as low grade fuels such as *lignite* can be used as reducing agents for the iron ore and the furnaces use only approximately 40% of the amount of carbon required for a blast furnace, heat for reduction being supplied by electric power. In addition, the gas given off is valuable fuel.

Tyuyamunite. ($CaO.2UO_3.V_2O_5.4H_2O$.) A vanadium ore.

U

U. Chemical symbol for *uranium*.

Ubbelohde Drop Point. The temperature at which a melted substance separates from the mass by its own weight.

Uchatius Process. A process, patented in 1855, of partially decarburizing pig iron by fusion with iron ore.

impression and prevent removal without distortion if forged into the impression while the metal is hot.

Underdraft. The tendency of metal to curve downwards when leaving rolls, because of lower surface speed of the lower roll. (A. 27.)

Underfill. (*a*) In rolling, a cross-section which has not filled the *roll pass* and is therefore not true to dimensions. (*b*) That portion of a die forging which lacks metal to give it the true shape of the impression. Shortage of metal exists because the hot plastic metal did not completely fill the die impression.

Underfilm Corrosion. Randomly distributed corrosion (occurring under lacquers and similar organic films) in the form of hairlines or spots.

Underflushing. A reduction in metal thickness due to excessive dressing. The imperfection produces a characteristic appearance of extended dark areas with diffuse edges.

Underhand Weld. A *weld* made in a surface lying horizontally or at an angle not more than 45° to the horizontal, the weld being made from the upper or top side of the parts joined.

Undermining Pitting. A type of corrosion attack in which *pitting* develops on the exposed surface and spreads out beneath the surface. (A. 27.)

Underpoled. (See Poling.)

Undersize. That portion of crushed or ground material which passes through a sieve of a specified mesh.

Understressing. The term as used in *fatigue testing* refers to the practice of subjecting a test piece to a certain number of cycles of stress below its normal *fatigue limit* before submitting it to a higher stress.

Underwater Cutting. The process of cutting metals under water into which divers may descend, using oxygas or electric arc process. (K. 7a.)

Unequal Draft. Irregularity in rolled metal, i.e. it is lighter on one edge due to non-parallel rolls.

Unicam S.P.600 Spectrophotometer. An instrument for *colorimetric analysis* of liquids and transparent solids in the visible and near infra red regions. It consists essentially of a controlled light source feeding a *Littrow monochromator*. This monochromator selects appropriate wavebands of light which pass through the substance under test and fall upon photoelectric cells. The *e.m.f.* thus produced is amplified and then balanced by a potentiometer. The scale of the potentiometer is calibrated in both percentage transmission and optical density.

Unichrome. A dip treatment applied to die castings. It forms a coating consisting of zinc oxide and zinc chromate. Its appearance is claimed to be similar to chromium plate. (D. 28.)

Union Melt Welding. (*Submerged Arc* or *Ellira Process*.) An automatic electric welding process in which a bare wire electrode is used and granulated powder takes the place of the coating. This powder is fed on to the joint ahead of the electrode, the end of which is completely covered by the powder. (R. 1.)

Unit Cell. The smallest group of *atoms*, *ions*, or *molecules* whose repetition at regular intervals, in three dimensions, produces the lattice of any given crystal.

Unit Cube. The *unit cell* in cubic crystals.

Unit of Structure. In crystals, the group of atoms included by the unit cell, especially if the arrangement of the group indicates chemical relations among its members. (A. 27.)

Unit Sand. (See Standard Sand.)

Unit Strain. The change in dimensions per unit length.

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Uni-Temper Mill. A rolling mill used for the *temper rolling* of cold reduced strip. It consists essentially of two 2-high mills built into the same *housing*, the roll setting of the top mill being controlled by a conventional *screwdown*, whilst that of the bottom mill is set independently by a screw-up. The bottom roll of the top mill and the top roll of the bottom mill are fixed in spatial position, and are the driven rolls. The extreme top and bottom rolls are idle, being driven by frictional contact with the strip only. The strip enters between the top pair of rolls and wraps around the No. 2 roll (counting downwards) and then around the No. 3 roll, and then through the bite of the bottom pair of rolls. By virtue of the strip wrapping around the driven rolls, No. 2 and No. 3, they serve to act as tension multipliers as well as to roll the strip slightly, so that, whereas the tension in the strip is slightly above the yield point in the stretch gap, it is reduced to hardly more than half this value at the exit point from the top mill or at the entry point to the bottom mill. The work of the second or lower *2-high mill*, in addition to its functions as the pulling pair of rolls and tension multiplier, is to

perform a slight rolling operation, thus burnishing the strip. (S. 142.)

Uniting Pressure. The pressure at which the individual particles of a metal powder will unite together to form a solid mass of metals, e.g. lead 13 tons per sq. in., tin 19 tons per sq. in., copper 33 tons per sq. in., aluminium 38 tons per sq. in.

Univalent. (See MONOVALENT.)

Universal Mill. (See ROLLING MILL.)

Universal Mill Beam. A structural steel beam rolled between horizontal and vertical rolls.

Universal Plate. Plate or slab produced in a *universal mill* to the specified finished width and sheared to the specified length.

Universal Plate Mill. A mill having both horizontal and vertical rolls. The horizontal rolls control the thickness and the vertical rolls control the width during the rolling of plates.

Universal Rolling. Rolling slab or plate in a mill equipped with vertical edging rolls. These give a smooth edge and enable the width of the product to be accurately controlled.

Universal Self-Indicating Machine. (See AVERY SELF-INDICATING MACHINE.)

Universal Testing Machine. An instrument so designed that it is capable of exerting a *tensile*, *compressive*, or *transverse* stress on the specimen under test. Further, it can be adapted for the determination of *Brinell hardness*, *ductility*, *cold bend* and other properties. The machine consists essentially of three systems: loading, weighing and indicating, the loading being applied either mechanically or hydraulically.

Universal Welding Head. A welding head which can be adapted either to circumferential or longitudinal seam welding.

Uniwelding. A method of welding accomplished by butting together under pressure two machined faces of parts to be welded, at the same time heating the area of the weld plane until sufficient upsetting takes place. The essentials of the process are intimate contact of surfaces to be welded, heat, pressure and exclusion of air or any material that might cause physical or chemical discontinuity between the butting weld faces. Bonding is the cohesion of metal at the weld plane due to atomic attraction effected by the intimate contact of the weld surfaces. In a practical sense, hot working (upsetting) is the agency by which intimate contact is effected in this process. Hot working also serves to break down inhibiting films on the weld faces and cause recrystallization across the weld plane. Further re-orientation of grains is produced by the transformation that takes place in a low alloy steel during subsequent heat treatment. (W. 22.)

Unkilled Steel. Steel which has been insufficiently deoxidized and evolves gas during solidification, with the formation of *blowholes*. This should be distinguished from other forms of *wild steel*. In the case of unkilled steel, the blowholes are formed as a result of the production of carbon monoxide by reaction of iron oxide with carbon. Similar occurrences may arise from the presence of excessive amounts of hydrogen and/or nitrogen. (See RIMMING STEEL INGOTS.)

Unshielded Arc Welding. Welding with an open arc, i.e. the arc is not protected from the atmosphere.

Unsoundness. The condition of a metal which contains *blowholes*, *contraction cavities*, or *porosity*.

Unstable. Subject to spontaneous change.

UO_2. Chemical formula for uranium oxide.

Upcut. (See CUT.)

Upended Forging. (*Upset Forging.*) A *die forging* so produced that the *grain flow* tends to be at right angles to the face of the dies. (See also OMES ELECTROFORGING PROCESS.)

Upending Test. (See UPSETTING TEST.)

Uphill Casting. (*Bottom Casting* or *Bottom Pouring.*) A process in which the steel is poured from the ladle into a centre runner, or *trumpet*, connected at its base with a system of runner bricks which distributes the steel to the moulds. The moulds are set in a predetermined fashion on a specially designed bottom plate having channels for runner bricks, and the runner brick under each mould has an outlet on the top surface to permit the entry of the steel into the mould. (W. 13.)

Uplift. The charge added to the wholesale price for the purpose of purchase tax calculations

Upper Punch. In *powder metallurgy*, the member of a die assembly that moves downward into the die body to transmit pressure to the powder contained in the die cavity. (A. 27.)

Upset Butt Welding. (See UPSET WELDING.)

Upset Forging. (See UPENDED FORGING.)

Upset Frame. The term applied in a *foundry* to a shallow frame set over a *flask* in which is formed a green sand *match*. It is also used to deepen a *cope* or *drag*.

Upset Test. (See UPSETTING TEST.)

Upset Welding. In this process the pieces are brought together under pressure, current is applied and the heat created at the joint fuses the parts

together. Pressure is continued and the pieces are held together until the temperature has dropped below the plastic point. (S. 103.)

Upsetting. Working a piece of stock in such a way that its length is shortened and the cross-sectional area is increased. It has the effect of increasing the ductility in both the radial and transverse directions.

Upsetting Force. In *flash* and *upset welding*, the force exerted at the welding surfaces during *upsetting*. (A. 37.)

Upsetting Test. (*Dump-*, *Jump-*, *Knock Down-*, *Slug-* or *Upending-Test.*) A test for forgeability. For *cold forging*, a sample of the steel is hammered in the cold, parallel to its axis until it is reduced by a specified amount without cracking. For *hot forging*, the sample is heated to a suitable forging temperature, then subjected to severe compression under a hammer. The compression or upsetting action will force open any defects which could not be detected while the steel was in the as-rolled condition.

Upsetting Time. In *flash* and *upset welding*, the time during *upsetting*.

Upside Down Charging. The method sometimes employed of placing cold ingots upside down in the *soaking pit*, as distinct from normal practice in which the ingots are charged whilst still hot, i.e. immediately after stripping, and in the upright position.

Upton-Lewis Fatigue Testing Machine. A machine for the application of flexural reversed stress in which calibrated springs are used to resist and measure the bending moment applied to the specimen, which is bent back and forth in one plane. The amount of deflection of the springs, and hence the magnitude of the bending moment applied to the specimen, is given by the width of the diagram drawn by a pencil point. The number of cycles of bending stress is shown by a counter. The machine operates at a speed of 300 r.p.m. (M. 159.)

Upton Salt Bath Furnace. A salt bath furnace in which the electrodes are completely submerged beneath the salt. (G. 22.)

Uranium. (*U.*) *Atomic weight* 238·07. *Specific gravity* 18·7. *Melting point* 1130° C. In massive form, a lustrous white malleable metal capable of taking a high polish. Pure uranium is highly ductile, but small amounts of iron and aluminium in it cause embrittlement. It is unattacked by air at ordinary temperatures, but burns brilliantly at 170° C. When struck with a hard substance it emits copious sparks. It reacts with boiling water, and dissolves freely in most mineral and a few organic acids. Its salts are remarkable for their extreme fluorescence. Uranium is chiefly derived from *pitchblende*. Until recently, there were comparatively few uses for uranium, but all previous applications have now been completely dwarfed by its use in the atomic bomb and as a potential source of atomic energy. The effect of uranium on steel has been investigated and it has been shown to have some slight strengthening effect, but similar results can be achieved by cheaper means and as far as the writer is aware uranium steels have never been produced commercially.

U.S.A.A.F. United States Army Air Force.

U.S.A.F. United States Air Force.

U.S.A.N.Aer. United States Army-Navy-Aeronautical.

U.S.A.S.C. United States Army Signal Corps.

U.S.Fed. United States Federal Specifications Board.

U.S. NAVAER. United States Navy Department (Aeronautical).

U.S. Naval Research Laboratory Drop Weight Test. (See DROP WEIGHT TEST.)

U.S. Navy Tear Test. (See NAVY TEAR TEST.)

U.S.N.B.S. United States National Bureau of Standards.

Use. The preliminary and roughly shaped *drop forging*.

V

V. (*a*) Chemical symbol for *vanadium*. (*b*) Abbreviation for vertical welding position.

Vacu-Blast Descaler. A machine for cleaning metal surfaces by a process which can be regarded as a development of sand-blasting. Grit is directed through a gun on to the surface to be cleaned, and is then sucked back through the gun, together with the scale or paint removed from the surface into a reclaiming tank. Here the dust is separated from the grit, and it is then passed into a dust collector. An alternative gun is provided for use at right-angled intersections. The machine consists of three units, the gun, the reclaiming tank, and the dust collector. (A. 8.)

Vacuum. An empty space. The term is generally taken to mean a space containing air or other gas at very low

pressure, as a perfect vacuum is theoretically unobtainable since every material which surrounds a vacuum has a definite vapour pressure.

Vacuum Casting. A technique for producing steel ingots which degases the steel. The procedure is as follows: on entering the vacuum, the steel is more or less broken up, according to the size of the vacuum, the diameter of the stream of steel flowing from the ladle, and the rate of casting. Although normally a compact casting stream is desired, the vacuum procedure results in the opposite effect; the liquid steel is split up into innumerable drops, which expand in the vacuum until they explode, give up their gases and thereafter shrink considerably. During the casting process, which lasts from 15 to 30 minutes, the temperature of the steel is registered automatically and the cast can be observed through quartz windows. The process is applied commercially to ingots of up to 150 tons. (See also *Wetherill Casting Process*).

Vacuum Dilatometer. A device for measuring the thermal expansion of rods about 3 in. long. The expansion is transmitted by a silica rod to a dial gauge. The specimen, enclosed in a silica tube and under vacuum, is heated in an electrical resistance furnace at about 6° C./min. Temperature is measured by a platinum/platinum-rhodium thermocouple in a small hole at the centre of the specimen. (L. 4.)

Vacuum Etching. (See CATHODIC ETCHER.)

Vacuum Metalling. (*Evaporation Coating.*) Plating or metallizing by high vacuum evaporation based on the principle that metal vaporized in a vacuum travels in a straight line until it encounters some object. Upon contact, condensation occurs and the object is coated, aluminium being the most common coating agent. The articles to be coated, together with the coating metal placed on filaments, are introduced into a bell jar, or in large industrial units, a steel tank, which is evacuated to the required degree, and low voltage current is fed to the filaments which become incandescent and heat the coating metal to a point where it boils and vaporizes. The metal vapour thus generated condenses, producing a bright coating of microscopic thickness. *Cathode sputtering* differs in that the metal to be coated is transferred to the article by high voltage bombardment rather than by direct thermal evaporation. Equipment required is similar to the evaporation unit except that a more moderate vacuum with provision for adding an inert atmosphere is required, and a high voltage rather than high amperage power supply is employed. The sputtering process is used mainly in work with precious metals. It is not used in high production, since the rates of metal transfer are comparatively low. (F. 39.)

Vacuum Metallurgy. (*Vacuum Refining.*) Melting metals in the absence of gases, usually by electrical induction, with the object of producing products of high quality and purity. (D. 7.)

Vacuum Refining. (See VACUUM METALLURGY.)

Vacuum-Tube Rectifiers for Dynamic Testing Machines. An application of the *thermionic valve* to a dynamic transverse bending machine. The test bar is suspended between the poles of two electromagnets which are excited so that the bar vibrates in resonance. The current to the coils of the electromagnets is controlled by a thermionic valve having a common *cathode*, two grids, and two anodes; contacts on the bar are connected to the grids, and these control the current to the anodes. (M.24.)

Valency. The valency of an atom or group of atoms is the number of atoms of hydrogen which it will displace or combine with in a chemical compound.

Vallaroche Scleroscope. A hardness testing instrument, developed in France, based on the same principle as the *Shore scleroscope*, the hardness being measured by the height of the rebound. (J. 22.)

Vallium Process. A proprietary process for hot *galvanizing* wire rope.

Valve Effect. A characteristic of certain materials to pass electric current in one direction only, thus qualifying these materials for applications in electric rectifiers. (A. 27.)

Van Arkel Process. (*Iodide Process.*) (*a*) As applied to titanium, the first process which produced titanium in a form suitable for working. It is based on the thermal decomposition of titanium tetraiodide to titanium metal and iodine. The reaction is reversible, depending on the temperature, and it is possible to produce titanium tetraiodide by reacting crude titanium with iodine at one temperature and then decomposing this by increasing the temperature to produce pure metal and release the iodine which may be used again to repeat the cycle. In practice, lumps of crude metal produced by the calcium or sodium reductions of titanium dioxide are charged around the periphery of a glass tube and retained in this position by a perforated molybdenum cylinder. A filament of titanium is attached to metal leads sealed into the glass head.

A side arm is charged with iodine and cooled during the evacuation and sealing of the vessel. The filament is heated to 1100° to 1500° C. by passing current through it and the crude metal is heated to about 250° C. when the first reaction takes place, i.e. the production of tetraiodide which then volatilizes and its vapour fills the vessel, contacting the hot filament, resulting in thermal decomposition, the titanium being deposited on the filament and the iodine, as vapour, returning to react with more crude metal. The titanium decomposition continues until a thick hairpin of metal is produced. (*b*) The above method applied to the production of ductile *zirconium* by the thermal decomposition of zirconium tetraiodide to the elements zirconium and iodine. (M. 140.)

Van der Horst Process. (*Porus-Krome.*) A method of chromium plating to produce an oil-retaining surface on cylinder walls of internal combustion engines. The coating is produced chiefly by a post-plating etch carried out by reversing the current. This causes the whole surface to be broken into a network of visible cracks with plateaux between them, which retain oil and so confer free running properties. It is claimed that this technique overcomes the tendency to *seizing*, characteristic of normally deposited chromium, owing to the fact that the surface is not wetted by oil. (M. 106.)

Van der Veen Brittle Fracture Test. A notched slow bend test for the determination of the tendency to brittle fracture of steel plates. The dimensions of the test specimens are: t × 70 × 225 mm. (t = plate thickness). The longitudinal axis of the bar is generally taken perpendicular to the direction of rolling. In the middle of one of the machined sides (dimensions t × 225 mm.), a sharp, 3 mm. deep notch is pressed with an included angle of 45° and a fairly constant root-radius of about 0·04 mm. The axis of the notch is perpendicular to the plate surfaces. Mill-scale is not removed. Specimens include the full thickness of the plate. The fracture is made to propagate in a direction parallel to the plate surfaces and is started from a sharp notch. Specimens are loaded by slow bending. Slow bending makes possible the recording of load-deflection diagrams and thereby the measurement of various criteria for brittle fracture. Usually, two transition-temperatures are determined (*ductility* and fracture appearance). The determination of the latter is facilitated by the minimum tendency to start cleavage appearing to exist at the neutral axis of the bar. Both temperatures may be determined without the recording of a load-deflection diagram. The evaluation of brittleness is based only on types of diagrams and fractures and not on absolute values of certain criteria, such as energy to fracture. (V. 8.)

Van Orstrand-Dewey Method. A method for the determination of the diffusion coefficient of carbon in alpha iron below 725° C.; above 725° C. this method cannot be applied. Two cylinders, one of high carbon corresponding to a composition close to the eutectoid, and the other essentially carbon-free are welded together into a diffusion couple. This diffusion couple is then annealed to diffuse the carbon across the weld or interface. After the diffusion anneal, the distribution of carbon with respect to the interface is determined, the concentration-penetration curve is plotted, and the curve is analysed mathematically for the diffusion coefficient. (S. 102.)

Vanadinite. A vanadium ore, consisting essentially of lead vanadate.

Vanadisel Foundry Composition. A non-thermosetting petroleum pitch, free from products volatile below about 295° C. (K. 20.)

Vanadium. (*V.*) *Atomic weight* 50·95. *Specific gravity* 6·0. *Melting point* 1710° ± 10° C. The most important vanadium bearing minerals are *carnotite*, *roscoelite* and *patronite*. Pure, ductile vanadium metal can now be obtained in massive form for remelting, as well as in ingots, bars, sheet and foil. The metal is lighter than iron, has good structural properties, and resists pitting and corrosion by salt spray and sea water. It can be rolled at ordinary temperatures; cold reductions up to 85% have been made without annealing. Pure vanadium machines well and is easily welded with regular shielded arc methods. The presence of vanadium in steel raises the temperature at which grain coarsening sets in and under certain conditions increases the hardenability. It also lessens the softening on tempering and confers secondary hardness on high speed and certain other steels. It is an active grain refiner and is a strong deoxidant. Vanadium is an important constituent in many types of steel, for widely varying applications, e.g. nitriding and heat resistant steels, tool steels and steels for wearing plates and other fully hardened parts. In conjunction with molybdenum and/or tungsten, vanadium has a marked effect in enhancing creep resistance.

Vanadium Mica. (See ROSCOELITE.)

Vanadium Steel. (See VANADIUM.)

Vanadium Pentoxide. (V_2O_5.) Used for the addition of *vanadium* in basic electric furnace steelmaking.

Vanadoferrite. (See FERROFERRITE.)

Vanoxite. ($2V_2O_4.V_2O_5.8H_2O$.) A vanadium ore.

Vanstoning. A method of shaping stainless steel tube in the field by means of a hydraulically operated machine which rolls the end of the tube to the required form. (F. 45.)

Van't Hoff Factor. A factor, the product of which, with the molecular weight of an electrolyte calculated from freezing point law, gives its real molecular weight.

Van't Hoff Law. When the temperature of a system in equilibrium is raised, the equilibrium point is displaced in the direction which absorbs heat.

Vaporimeter. An apparatus in which the volatility of oils is estimated by heating them in a current of air.

Vaporization. The conversion of a liquid or a solid into a vapour.

Vapour. A gas which is at a temperature below its critical temperature and can therefore be liquefied by a suitable reduction in pressure.

Vapour Blast. This process of metal surface finishing consists of directing a blast of water and fine particle abrasive mixture at high velocity by means of compressed air against the surface to be treated. The abrasive medium is selected from the standard range and may be from 80 to 2500 mesh, according to the class of work and finish required Compressed air at 80 or 100 lb./sq. in. is normally used and a rust inhibitor may be introduced into the mixture to prevent rusting of the treated parts. Very low coefficients of friction are claimed for vapour blasted surfaces under boundary conditions of lubrication. This is partly due to the degree and type of surface finish and also to the capillary properties of such a surface. (M. 103.)

Vapour Flux Brazing. A blowpipe brazing process in which the necessary flux is carried in the fuel gas to the joint, no flux being preplaced in the joint. The flux is dissolved in a highly volatile and inflammable liquid, the vapour from which is picked up by the fuel gas in a dispenser and carried to the blowpipe nozzle. Here the liquid burns and deposits the required quantity of flux in the joint area. (M. 88.)

Vapour Galvanizing. Coating steel with zinc by exposure to zinc vapour.

Vapour Pressure. The pressure exerted by a *vapour*, either by itself or in a mixture of gases. The term is often taken to mean saturated vapour pressure, which is the vapour pressure of a vapour in contact with its liquid form. The saturated vapour pressure increases with rise of temperature.

Vapour Welding. A process of *evaporation coating*, where metals are vaporized in an inert atmosphere, under a very high vacuum, and deposited on other materials which may be metallic or non-metallic. (See VACUUM METALLING.) (D. 27.)

Variable Voltage Welding Source. A source of electric power, the voltage of which automatically falls as the current increases, but of which the power is not constant.

Varimag Permeameter. A simplified form of *permeameter* which can be used for the routine testing of magnet steels and other materials. The changes of flux in the test piece are measured by means of a special fluxmeter and the magnetizing force by means of a magnetometer of appropriate range. It is claimed that steady readings on both instruments are obtained during observations and results can be worked out quickly. Normal B/H curves, and *hysteresis loops* can be determined. The *flux* for excitation of the test piece is provided by a variable permanent magnet fitted with D-shaped soft iron pole pieces. The flux is varied by turning the magnet on its axis in a tunnel gap; this arrangement replaces the usual magnetizing current supply, coil, ammeter, *rheostats*, reversing switches, etc. (M. 135.)

Varnish. An organic coating, consisting of a solution of gum resin in a mixture of boiled oil, e.g. linseed oil, and oil of turpentine, which dries and hardens, by evaporation of the solvent and oxidation of the oil, thus forming a smooth glossy surface.

Varnish-Lacquer. A brittle lacquer for *stress analysis*. It is a liquid, non-toxic lacquer which is sprayed on in thin layers by atomization. The solvent is driven off by flame heating and there remains a coating of smooth glossy lacquer which cracks when the underlying steel is stretched, thus permitting an exact location of area maximum stress. (See STRESS-COAT DRILLING.) (G. 72.)

Vauquelin, Louis Nicolas. (1763–1829.) A French chemist, who discovered chromium in 1797.

V.D.E. *Verein Deutscher Eisenhüttenleute.*

V.D.G. *Verein Deutscher Giessereifachleute.*

V.D.M. Verein Deutscher Materialsprüfung.

Vector. A straight line of a definite length drawn from a given point in a given direction. A vector may represent a quantity, such as a velocity, which has both magnitude and direction. Such a quantity is called a *vector quantity*.

Vector Quantity. A quantity, such as the intensity of an electric or magnetic field, which has direction as well as magnitude. Represented graphically and mathematically as a line the direction of which represents the direction of the quantity and the length of which represents the magnitude in terms of a unit *vector*.

Vector Ratio. The ratio between two alternating quantities, e.g. currents, in which both relative amplitudes and phases are expressed in the form of *vectors*.

Vee Joint. A *scarf* joint where the abutting ends of the parts to be welded are respectively wedge-shaped and V-shaped.

Vegard's Law. The lattice *parameters* of substantially solid solutions vary linearly with composition expressed in atomic percentages. (A. 27.)

Vehicle. A liquid carrier for pigments in paints, which dries to form a film, e.g. linseed oil.

Veining. (*a*) (*Mapping*). Rough, irregular crack-like projections on the surface of castings which can only be removed by chipping or grinding. (*b*) (See SUB-BOUNDARY STRUCTURE).

Velocity Constant. The speed of a chemical reaction, in gram-molecules of change per litre per second, when the active masses of all the reactants are unity.

Velocity of Light. A universal constant denoted by c, for the velocity of all electromagnetic waves, equal to $(2{\cdot}99796 \pm 0{\cdot}00004) \times 10^{10}$ cm. per sec. in vacuo (186,000 miles per sec.).

Velocity of Sound. Measurements of the velocity of sound in air obtained by various physicists are in close agreement, giving a value of 331·7 metres per second.

Velocity Sensitivity. A measure of the capacity to deform suddenly and rapidly before failure, revealed by *impact testing*.

Vena. (*a*) The Latin equivalent of vein. (*b*) An iron ore found in Spain, in small quantities only. It contains about 60% of metallic iron.

Vent. A small hole in a mould to allow the gases to escape.

Vent Wire. (*Piercer.*) A length of steel wire, about 3 to 4 ft. long and $\frac{1}{16}$ to $\frac{1}{8}$ in. diam., according to the size of the *mould*, used to bore the sand after ramming, to form a *vent* and thus allow the rapid escape of gases generated during casting.

Venting. The perforation with a *vent wire* of the sand over and around a mould cavity.

Venting Quality. The *permeability* of sand.

Venturi Tube. An apparatus for recording rates of flow through closed pipes; it consists of a constriction inserted in the line of piping, together with means for measuring the loss of head over the convergent part of the constriction.

Verdet's Constant. The rotation of the plane of polarization per cm. per unit magnetic field in the *Faraday effect*. The value of the constant varies with temperature and is approximately proportional to the square of the wavelength of the light.

Verdigris. A very poisonous copper salt varying in colour from green to blue.

Verein Deutscher Eisenhüttenleute, Dusseldorf, Breite Strasse 27. The German equivalent of the Iron and Steel Institute.

Verein Deutscher Giessereifachleute, Dusseldorf. German Foundrymen's Association.

Veritas Limit. The term given in France to the value giving a *creep* rate of 5×10^{-4}% per hour between the 25th and 35th hours of the test.

Vermiculite. Micaceous or plate-like minerals in form of hydrated silicates which exfoliate on heating to many times original size, and are used in the steel industry as a foundry-sand binder, for core washes and for mould facings.

Vernier. A device for measuring subdivisions of a scale. For a scale graduated in inches and tenths, a vernier consists of a scale which slides alongside the main scale, and on which a length of nine-tenths of an inch is subdivided into ten equal parts. Each vernier division is then 0·09 of an inch. If it is desired to measure a length AB, the main scale is placed with its zero mark at A, and the vernier scale is slid till its zero mark (the "V" of the vernier) is at B. By noting which division on the vernier scale is exactly in line with a division on the main scale, the second decimal place of the length AB is obtained. (L. 34.)

Verso. The left-hand page of an open book, bearing an even number.

Vertical Double Pillar and Slit Gate. A method of running and feeding which is common practice in the magnesium foundry. It consists of a vertical pillar or cylinder flanked for its entire height by a narrow *gate* which leads into a pillar of similar diameter, also flanked

by a narrow *slit gate*, and thence into the casting.

Vertical Mill. A *rolling mill* in which the rolls operate vertically.

Vertical Position. (*a*) The position of welding, wherein the axis of the weld is approximately vertical. (*b*) In pipe welding, the position of a pipe joint wherein welding is performed in the horizontal position and the pipe may or may not be rotated. (A. 37.)

VGB Test Piece. An impact test piece recommended for low temperature tests; it is 160 mm. × 30 mm. × 15 mm. and has a keyhole notch 15 mm. deep and 4 mm. diameter.

Vi. Chemical symbol for *virginium*.

Vibration Galvanometer. (See GALVANOMETER.)

Vibration-Measuring Instrument. A high-frequency pulsator for measuring vibration and *damping*. The machine produces controlled tensile and compressive forces by means of a magnet. The force is measured optically by a thin-walled tube in series with the specimen, the elastic deformation of which turns a small mirror; this deflects a beam of light across a suitable scale. (R. 52.)

Vibrator. A device, operated by compressed air or electricity. It may be used for example, for loosening and withdrawing patterns from a mould, or for consolidating sand in a mould.

Vibrophore. (See AMSLER VIBROPHORE.)

Vibrator Frame. A frame in which *patterns* are mounted when they are to be drawn in connection with a vibrator.

Vibroscope. (See LEAK VIBROSCOPE.)

Vickers Diamond Hardness Tester. An indentation hardness machine, which employs a diamond with a 136° pyramid. Tables for converting ocular readings of the diagonals of the impression in mm to *Vickers Pyramid Hardness Numbers* (*V.P.N.*) are supplied. Brinell hardness numbers using a 1 mm. ball/30 kg. load, or a 2 mm. ball/120 kg. load can also be determined. Loads ranging from 1 kg to 100 kg. can be used with the diamond indenter.

Vickers Pyramid Hardness Number. (See VICKERS DIAMOND HARDNESS TESTER.)

Villari Effect. (See MAGNETOSTRICTION.)

Villela and Bain's Method. A method of revealing austenite grain size in fully hardened steels by using *Villela's reagent* which develops contrast between *martensite* grains having different orientations.

Villela's Reagent. An etching reagent consisting of 95 ml. ethyl alcohol, 5 ml. hydrochloric acid and 1 g. of picric acid.

Vinci, Leonardo Da. Born April 14, 1452, at the Tuscan village of Vinci. Died May 2, 1519. He achieved great eminence both in art and science and was an engineer of considerable skill. (E. 29.)

Vinylite Polyvinyl Butyral Resins. These resins have been used as precoatings for the undersides of naval craft to ensure adhesion of subsequent coating and to give improved resistance against corrosion and fouling. (B. 98.)

Virgin Metal. (*Primary Metal.*) Metal obtained directly from the ore, and not previously used, in contradistinction to metal remelted from scrap or previously fabricated material.

Virginium. (*Vi.*) An element which is theoretically conjected to belong to the alkali metal family. Neither the metal nor any of its compounds have been isolated.

Virgo Salt Descaling. (See HOOKER VIRGO SALT DESCALING.)

Viscometer. An instrument for measuring *viscosity*.

Viscosity. The definite resistance shown by fluids to change in form due to molecular cohesion. The coefficient of viscosity is the value of the tangential force per unit area which is necessary to maintain unit relative velocity between two parallel planes unit distance apart. Viscosity varies inversely with temperature.

Viscous. Having high *viscosity*; a liquid which "drags" in a treacle-like manner.

Visible Sound Method. (See POHLMAN METHOD.)

Vitreosil. The proprietary name for the manufactured form of pure fused silica glass

Vitreous. The term applied to a body that has undergone *vitrification*.

Vitreous Fracture. (See FRACTURE.)

Vitrification. The high temperature conversion of refractory material into glass. It is usually associated with reduction in porosity.

Vitrification Point. The temperature at which clays reach the condition of maximum density and shrinkage.

Vitriol. (*Oil of Vitriol.*) Concentrated sulphuric acid, H_2SO_4; *Blue vitriol* is copper sulphate, $CuSO_4.5H_2O$; *Green vitriol* is ferrous sulphate, $FeSO_2.7H_2O$; *White vitriol* is zinc sulphate, $ZnSO_4.7H_2O$.

Vivianite. (See BLUE IRON EARTH.)

V_2O_3. Chemical formula for vanadium oxide.

Void. (*a*) (See PORE). (*b*) A *shrinkage cavity* produced in castings during solidification. (See also PIPE). (*c*) In *powder metallurgy*, an unintentional empty space in a sintered compact

resulting from faulty technique. (See also POROSITY.)
Volatile. Readily evaporating at relatively low temperatures.
Volatilize. To convert into a gas or vapour.
Volatility. The tendency of a substance to vaporize at the temperature under consideration. (A. 27.)
Volborthite. A vanadium ore consisting essentially of copper vanadate.
Volt. The practical unit of *electromotive force*, equivalent to 10^8 electromagnetic units of potential. It represents that potential difference against which one *joule* of work is done in the transfer of one *coulomb*.
Volta Effect. An effect produced when two dissimilar metals are placed in contact with one another in air, one becoming positive and the other negative.
Volta Furnace. A three-phase direct arc electric furnace of the *Heroult* type.
Voltage. *Arc Stream Voltage.* The voltage drop along the arc stream in welding. *Open Circuit Voltage.* The voltage of a welding circuit between the electrodes, when no current is flowing. *True Arc Voltage.* The sum of the arc-stream voltage, the *cathode drop*, and the *anode drop* in welding. *Welding Arc Voltage.* The sum of the true arc voltage and the voltage drop in the electrode.
Voltage Regulator. An automatic electrical control device for maintaining a constant voltage supply to the primary of a welding transformer. (A. 37.)
Voltaic Cell. A source of electrical energy depending on chemical action and complete in itself, e.g. a primary cell, or an accumulator. It has two electrodes, each of which is immersed in an electrolyte and reacts therewith to produce an *e.m.f.*
Voltaic Current. An electric current resulting from chemical action.
Voltaic Pile. A source of direct current supply. It comprises a battery of primary cells in series, arranged in the form of a pile of discs, successive discs being of dissimilar metals separated by a pad soaked in the chemical agent.
Voltameter. An instrument for measuring a current by means of the amount of metal deposited, or gas liberated, from an electrolyte in a given time due to the passage of the current.
Voltmeter. An instrument for measuring *electromotive force* directly, calibrated in *volts*.
Volume, British Units of. (See Appendix II.)
Volume, Metric Units of. (See Appendix II.)
Volume Resistivity. (See SPECIFIC RESISTANCE.)
Volumetric. Pertaining to the measurement by volume as opposed to weight (*gravimetric*).
Volumetric Analysis. A method of chemical analysis in which the substance to be measured, which must be in the form of a solution, is determined by the addition of a known quantity of a reagent of standardized strength. This standardized solution is usually added by means of a graduated *burette* and in certain cases, e.g. the addition of a standard alkali to an acid, an indicator such as *phenol phthalein* is added which changes colour when the *end point*, i.e. neutrality, is reached. The process is known as *titration*. The amount of the element sought is calculated from the volume of standard solution required to reach neutrality.
Volumetric Modulus of Elasticity. (*Bulk Modulus* or *Modulus of Cubic Compressibility*.) When a body is subjected to external forces all around it (such as are due to total immersion in a liquid) there is a slight reduction in the *volume*. The volumetric modulus of elasticity is the number by which the stress upon the exterior of the substance must be divided to give the unit diminution in volume or cubical strain.
Vom Baur Furnace. An electric arc furnace which is elliptical in plan and has three carbon electrodes arranged in a straight line. It can be operated with three-phase current but two-phase current is preferred.
Votta Wire Fatigue Testing Machine. An instrument for the application of rotating beam fatigue tests to wire. One end of the specimen is held in a rotating chuck, the wire is bent into a semi-ellipse and the free end inserted in an adjustable bush in which it is free to rotate. Simple supports keep the loop horizontal and prevent vibration. The chuck rotates at 3600 r.p.m. and can test wire of up to 0·03 in. diam. (V. 14.)
V.P.I. (*Vapour-Phase Inhibitor.*) A chemical compound which in its vapour phase inhibits, or prevents, the corrosive action of oxygen on metal which otherwise would occur in the presence of moisture. It is claimed that a minute coating of V.P.I. dispersed in a coating on paper or paperboard will give corrosion protection to an article, sealed in the package, for many months. (M. 148.)
V.P.N. *Vickers Pyramid Hardness Number.*
V Ratio. The ratio of lime to acid constituents in the *slag*.
Vroonen Process. A method for the rapid refining of molten metals in which

the metal and slag are poured into a long, narrow, funnel-shaped vessel, inclined at an angle, which is rotated about its axis. The slag and metal become intimately mixed, thereby enabling rapid refinement to take place, while at the same time the purified metal is thrown by the centrifugal action to the walls of the funnel. From the bottom of the funnel the pure metal flows out into a collecting vessel, the remaining emulsion of metal and slags forming a *core* as its axis. In the collecting vessel the emulsion floats on top of the purified metal, and the latter is withdrawn from the bottom. (V. 15.)

V.S. Abbreviation for *volumetric* solution.

Vug. (*a*) A *cavity* in rock or a lode, usually lined with crystals. (*b*) An obsolete term for *pipe* in a steel ingot or a cavity in a casting.

W

W. (*a*) Chemical symbol for *tungsten*, from the German *wolfram*. (*b*) British Standard specifications include a W. Series relating to wire specifications.

W-Arc. In *argon-arc welding*, an arc burning between the tungsten rod and the work plate, with its cathode on the tungsten. Similarly, *W-h.c.* is the straight polarity half cycle, i.e rod negative with respect to the plate whether an arc is present or not.

W-h.c. (See W-Arc.)

Wad. (*a*) Part of the *flash* which on being punched out leaves a hole in the *forging*. (*b*) *Bog manganese*, a mineral consisting mainly of oxide of manganese and water with some oxides of iron, silica, alumina and baryta. (*c*) *Earthy cobalt*, consisting essentially of oxide of cobalt.

Wagner Casting Machine. With this machine no *cope* is required. The *drag* and the core section are made of semi-steel; the former is fixed, and the latter can be raised into the casting position by a hydraulic ram. Both parts of the *mould* are heated to about 150° C. before casting, and they are coated with a refractory material after each cast. *Risers* are not used. Provision is made for passing a controlled amount of cooling oil through both the drag and the core to keep the mould at an even temperature. (I. 29.)

Waisting. (See Reduction of Area.)

Walbro Cupola. This is differentiated from other types of cupola in possessing a centrally disposed hole, which is never closed, in place of the normal tapping spout. A special receiver is used in conjunction with the cupola, which is ideally suited for the provision of small quantities of metal for continuous production. Carbon and sulphur pick-up is abnormally low, and the temperature of the metal as tapped is considerably higher than usual. Special attention is devoted to moulding and casting practice employed in conjunction with the Walbro cupola. (F. 7.)

Walking. A term employed in the U.S.A. for the inspection of the manufacture of certain types of steel products.

Walloon Process. A method, still used in Sweden, for the production of Swedish bar iron (*wrought iron*) formerly employed in the manufacture of *blister steel*. The furnace is built of unlined water-cooled cast iron plates and is provided with one *tuyere* through which a blast of air is driven. Very long *pigs* of white or mottled cast iron, specially cast for the purpose, are melted over the charcoal fire, being gradually pushed forward on rollers as their ends melt off. The drops of iron are partially decarburized as they pass through the air blast and thus the melting point is raised. The metal, as it reaches the hearth, forms a pasty mass which is continuously worked and when a lump of about 90 lb. has been obtained, the mass is raised above the level of the blast and worked again until the iron has been purified to the required degree. It is then removed from the furnace and hammered into a *bloom*.

Walterizing. A proprietary phosphate process applied to steel and zinc base alloys.

Walzel's Pendulum Impact Testing Machine. An instrument for the determination of impact hardness in which a 5 or 10 mm. steel ball is mounted on the striking edge of the pendulum of an *impact* machine and the specimen under test is attached to the anvil. The angle of rebound is taken as the measure of hardness. (W. 8.)

Wandering Block Sequence. In *welding*, a *block sequence*, wherein successive blocks are completed at random after several starting blocks have been completed. (A. 37.)

Wandering Sequence. (*Skip Sequence.*) A *longitudinal sequence* wherein the weld beads or layers of filler metal are deposited at random, e.g. by depositing a number of intermittent lengths or depositing additional lengths to previously made intermittent lengths, until a continuous length is finally attained.

Wanner Pyrometer. (See Polarizing Type of Pyrometer.)

Wap. A single turn in a coil of wire.

Warchol Pyrometer. A pyrometer for measuring steel bath temperature, which consists of a 3 in. steel tube 7 ft. long with an orifice at one end through which air is blown to keep the tube clear so as to allow radiation from the molten steel to reach the Rayotube cell situated about 11 in. up the tube. The millivolt output of the cell is passed to a high speed potentiometer recorder. (W. 9.)

Warding File. A thin flat file used by gauge makers and locksmiths in the making of keys and wards, hence the name.

Warm Strength. The term as used in the foundry refers to the strength of a *core* at temperatures in the range 65° to 150° C.

Warm Working. Essentially, this process consists in subjecting steels, after *solution heat treatment*, at about 1230° to 1300° C. to plastic deformation at a temperature in the range 650° to 800° C. This process is applied in particular to creep resisting steels, e.g. aero-engine gas turbine discs, in order to raise the tensile proof stresses which are normally low in austenitic discs. By this means, yielding of this disc due to the high centrifugal loads imposed in service, is avoided. The deformation carried out during warm working is actually one of cold working, in that the deformation is applied below the recrystallization temperature of the steel Normally, this is not attended by any decrease in creep strength, in fact, in many cases, an increase in creep strength occurs, and under certain controlled conditions, it can be raised very considerably by warm working. For instance, small rotor blade forgings have been made which showed an increase of approximately 50% in creep strength at 700° C. The reason for the enhancement of properties by this process is not merely due to cold work as with an ordinary 18/8 type of steel. Essentially, the warm working involves plastic strain at such a temperature that precipitation can simultaneously take place. It is, therefore, desirable to consider the type of precipitation which occurs, quite apart from the expected low temperature increase in proof strength due to cold work. (O. 6.)

Warman Penetrascope. A diamond pyramid hardness tester which is fully self contained and portable. It has a vice which enables it to be used for bar, sheet, etc., and it can also be utilized on large flat surfaces, for which purpose it is mounted on a rubber-wheeled platform. The load is applied hydraulically by turning a handwheel and the main electricity supply is stepped down by a transformer to supply the light used to illuminate the indentation seen through the microscope. (M. 52.)

Warpage. (*a*) Deformation other than contraction that develops in a casting between solidification and room temperature. (*b*) The distortion of wood through the absorption or expulsion of moisture.

Wash Bottle. A flask fitted with a two-hole rubber bung through which are passed two glass tubes. Tube A extends nearly to the bottom of the flask and is suitably bent at an acute angle at the top and connected by rubber tubing to a glass nozzle. Tube B which barely projects through the bung is bent at an obtuse angle. On blowing through tube B a stream of water is delivered through tube A. This flask is used in the chemical laboratory for washing filters, etc.

Wash Heat. (See Wash Heating.)

Wash Heating. (*a*) (*Washing*). In lining an open hearth furnace, the practice of adding a certain amount of old slag which is put on to the hearth, melted and immediately run off. (*b*) (*Cinder Heat* or *Swealing*). The soaking of an ingot at a high temperature under oxidizing conditions so that a considerable amount of the ingot surface is oxidized to a fluid slag, which runs off; surface defects on the ingot may be removed in this way. Alternatively, the part-cogged ingot, after a limited amount of rolling, may be recharged to the soaking pit and wash-heated, with the same end in view.

Washburn Core. A restricted neck core, i.e. a core of comparatively wafer thickness between two masses of metal, one of which is the head and the other the casting. These heat the core to a high temperature and enable the metal to flow freely through the reduced aperture between the head and the casting for a sufficient length of time to satisfy the feed demand of the casting. (D. 11.)

Washed Metal. American pig iron from which a considerable proportion of the original manganese, sulphur and phosphorus contents have been eliminated.

Washed Out. A term sometimes applied to tools which have had excessive wear.

Washes. (*a*) Defects in a casting resulting from the erosion of the sand by metal flowing over the mould or cored surface. (A. 26.) (*b*) (See Mould Wash).

Washing. (See Wash Heating.)

Washing Soda. (See Sodium Carbonate.)

Waste Waste. Tin-plate with more defects than those occurring on *wasters*.

Wasters. (*Seconds.*) Tin-plate having defects, a certain percentage of which are acceptable in normal consignments.

Water Annealing. A term applied to a method sometimes used in treating mild steel, in which it is cooled in air to a black heat and then immersed in water to accelerate cooling.

Water Core. A hollow water-cooled core inserted in a mould to accelerate cooling of the inner portions of the casting.

Water-Drip Test. A corrosion test in which drops of dilute (0·05%) sodium chloride solution are allowed to run down the inclined face of coated panels. Results are obtained in a comparatively short time, poor coatings showing signs of failure in less than ten minutes. (J. 28.)

Water Equivalent. The weight of water equal in thermal capacity to that of the apparatus, vessel or calorimeter used, when heat quantities are being determined, i.e. it is the heat absorbed by the apparatus expressed in terms of the mass of water which would be raised to the same temperature by the heat expended in heating the apparatus.

Water Gas. The general name for a mixture of gases obtained by the decomposition of steam by incandescent carbon. It usually contains from 43% to 44% carbon monoxide, 48% to 49% of hydrogen, 3% to 4% of carbon dioxide, and 3% to 4% of nitrogen. Used for heating and lighting.

Water Gas Welding. (See HYDRAULIC WELD PROCESS.)

Water Glass. (*Sodium Silicate.*) A viscous liquid which when mixed with powdered fireclay forms a refractory cement.

Water Hammer. A sharp hammer-like blow in a long pressure conduit caused by the rapid closing of valves. It may also be caused by the sudden collapse of steam bubbles on entering cold water. (A. 28.)

Water of Crystallization. The water present in crystals or in hydrated salts. These substances, when crystallized from solution in water, retain a definite amount of water, e.g. ferrous sulphate, $FeSO_4.7H_2O$.

Water of Plasticity. The water required to bring a clay to a good working consistency.

Water Pyrometer. (See HYDROPYROMETER.)

Water Separation. (See ELUTRIATION.)

Water-Spray Test. A corrosion test in which coated panels are placed at an angle of 30° to the horizontal, and tap water, maintained at about 20° to 25° C., is "rained" on them from a height of 2 ft. A cycle of 3 min. on, 3 min. off, is repeated until the first signs of corrosion appear. The test is intended to simulate direct exposure to the elements. (J. 28.)

Water Test. A test in which a casting is subjected to water pressure in such a manner that any porous areas will show leakage.

Waterteller. An instrument for the continuous electrical determination of the moisture content of core or moulding sand from a conveyor or mill. A stream of riddled sand falls on to a rubber-faced rotating disc. The sand is struck off to a constant volume and rammed by a roller to a predetermined hardness. The controlled ribbon of sand is then subjected to a high voltage potential and the current flows through the ribbon. The higher the moisture content the greater the distance the electrical current will flow and the moisture content is thus expressed in distance over a well-expanded scale. (F. 40.)

Watkin's Heat Recorder. A small block of fireclay with cylindrical holes containing pellets of materials melting at progressive temperatures.

Watt. Unit of power; the rate of work done in *joules* per second; the energy expended per second by an unvarying electric current of 1 ampere across a potential difference of 1 *volt*. Equivalent to 10^7 ergs per second. The power in watts is given by the product of the current in amperes and the potential difference in volts. 1000 watts = 1 kilowatt. 746 watts = 1 horse-power.

Watt Hour. The unit of electrical energy, being the work done by 1 watt acting for 1 hour, and thus equal to 3600 *joules* or $3{\cdot}6 \times 10^{10}$ *ergs*.

Watt Hour Efficiency. The ratio of the amount of energy available during the discharge of an accumulator to the amount of energy charged.

Watt, James. (1736–1819.) A Scottish engineer and the inventor of the steam engine.

Wattage. Electrical power measured in *watts*.

Wattful Current. The active component of an *alternating current*.

Wattmeter. Instrument for the direct measurement of the power in watts, of an electrical circuit, and provided with a scale graduated in watts, kilowatts or megawatts.

Wattmeter Method. A method of testing the electrical quality of iron specimens by measuring the power-loss with A.C. magnetization.

Wave-Length. The distance between corresponding phases of two consecutive waves; thus, the wave-length of the waves on water could be measured as the distance from crest to crest. Equal to the velocity divided by the frequency.

Wave Weld. A cold *welding* process in which the welding is carried out in a

wave line intersecting the grain of the metal. It is claimed that the finished work has no tendency to bend or buckle along the weld line. (D. 46.)

Waviness. A measure of surface irregularities. It has two ratings, width and height, the height being specified in thousandths of an inch, these measurements being maximum peak to valley heights.

Wax. Class of substances of plant, animal or mineral origin, insoluble in water, partly soluble in alcohol, ether, etc., and miscible in all proportions with oils and fats. Common waxes include beeswax, paraffin wax and Carnauba or Brazil wax. Mixtures of waxes are formed into rods and sheets and used for forming vents in *cores* and *moulds*.

Wax Pattern. Wax moulded round the parts to be welded by a thermit welding process to the form desired for the completed weld.

Wax Vent. A wax taper with a cotton wick, inserted into intricate *cores* during *moulding*. The wax melts during the drying of the core leaving a hole or *vent* for the escape of gas.

Ways. A term sometimes applied to the *guides* for the gate of a forging press.

Wazau Sheet Metal Tester. A ductility test for drawing cups from circular sheet blanks. The male die of 30 mm. diam. is motor driven and the drawing force exerted by it is measured by a hydraulic capsule, indicating the load. There are two ranges of sensitivity of 10,000 and 20,000 lb. for the standard type of the tester, which is built in higher capacities, if desired. (M. 131.)

Weak Sand. Sand lacking the proper amount of clay, bond or moisture. May be intentionally prepared to avoid cracking of intricate castings. (A. 26.)

Wear. A process by which material is removed from one or both of two surfaces moving in contact with one another, e.g. abrasion. Most wear phenomena have the common characteristic, namely, the mechanical overstressing of the surface material. Wear may be classified according to the manner in which the overstressing occurs. In single-sided wear or *erosion*, the contacting medium is a fluid, whilst double-sided wear is characterized by the presence of two mating solid surfaces. (B. 65a.)

Wear Tests. Tests carried out to determine the resistance of a specified material to *abrasion*. The tests may be carried out by various methods, e.g. by means of a grinding wheel or a revolving disc covered with a suitable abrasive, but in each case the conditions of loading, speed and lubrication must remain constant.

Weather Ometer. An accelerated *weathering* test apparatus. (A. 51.)

Weathering. (*a*) Exposing ore to the atmosphere for long periods in order that a part at least of the sulphide content may become oxidized and washed away by the rain. (*b*) (See SEASONING).

Weave Bead. A type of weld bead made with transverse oscillation. (A. 37.)

Weave Beading. The deposition of *weave beads*. (See WEAVING.)

Weaving. In *welding*, the technique of depositing filler metal or *weave beads* by oscillating the electrode.

Web. (*a*) A plate or thin member lying between heavier members. (*b*) (*Core*). In a twist drill, the central portion of the drill situated between the roots of the flutes and extending from the point end towards the shank; the point end of the web or core forms the chisel edge. (*c*) In forging, a thin section of metal remaining at the bottom of a depression and which is later removed. (*d*) The web of a crankshaft.

Webb Furnace. A furnace having three electrodes, arranged in line. It is designed for use with cold charges. Its chief feature is the employment of high voltages. (I. 20.)

Webb Rust-Proofing Process. An electrolytic process for the application of rust-proof, non-corrosive alloy coatings to the surface of steel or other metals. (E. 44.)

Weber Process. A method for the manufacture of pig iron in which the ore is mixed with a proportionate amount of coal sufficient to smelt it, and after adding a binder the mixture is briquetted by means of a roller press into ovoids, which are subjected to low temperature carbonization between 550° and 600° C., followed by smelting in a low shaft furnace. (L. 3.)

Wedge. A hardwood stick used as a forming tool in *spinning*.

Wedge Angle. (See RAKE.)

Wedge Compression Test. The specimen, in the shape of a round or square bar, is placed between two steel wedges, one vertically above the other and provided with hardened edges; pressure is applied and the bar is broken by the indentation of the wedges. In the case of unalloyed and not heat treated cast irons, the maximum pressure applied, when related to the original cross-section of the bar, gives a measure of the strength of the material. (L. 54.)

Wedge Curl Drop Test. A test for malleable cast iron in which a 21 lb. tup is repeatedly dropped 3½ ft. on a wedge

1 in. wide, $\frac{1}{4}$ in. thick at the butt and $\frac{1}{16}$ in. thick at the tip. The test is stopped after 30 blows or earlier if a crack appears. (F. 50.)

Wedge Drawing Test. (See SACH'S-WEDGE DRAWING TEST.)

Wedge Extensometer. A device to determine the bearing value of small rollers, in which a hardened steel wedge with a taper of 50 to 1 is inserted between two pins placed in the loaded roller and a third pin placed in the base of the load. Vertical movement is indicated by the distance to which the wedge can be inserted between the pins, and registered on a dial, one division being equivalent to a vertical deformation of 0·00002 in. Readings are taken in duplicate, pins and dials being provided on both sides of the roller, but only one wedge is used for the two sets of readings. (W. 63.)

Wedge Section. (See WEDGE SHAPE.)

Wedge Shape. (*Wedge Section.*) Strip in which the thickness tapers across its width.

Wedge Spectrograph. (*Slitless Spectrograph.*) An X-ray spectrograph in which the beams of incident and diffracted X-rays are limited by a wedge brought into contact with a face of the crystal.

Wedge Test. A hardness test for wire of up to 0·125 in. diam. It can be used on any type of Rockwell machine and for materials varying from dead soft aluminium to tungsten carbide. The wedge diamond indenter gives an impress which is practically an ellipse, of which the ratio of minor and major axes varies for both the diameter of the wire and the depth of penetration. This is in contrast to the Brinell and Rockwell impressions which are circular and to the Vickers which is square. Wedge readings are abbreviated as W-60, meaning a 60 kg. load, with a wedge-shaped diamond having an included angle of 120° and a radius of 0·008 in.

Wedgwood, Josiah, F.R.S. (1730–95.) A Staffordshire pottery manufacturer and the inventor of the *Wedgwood Pyrometer*. He was one of the first to appreciate the importance of the accurate determination of high temperatures.

Wedgwood Pyrometer. The oldest type of thermometer, devised by *Josiah Wedgwood*, for use in his pottery works. It was based on the shrinkage of dehydrated clay, it being assumed that the shrinkage was proportional to the temperature to which the clay was exposed. This was not strictly true, and this type of instrument is no longer used.

Weep Hole. A hole placed in a casting to allow drainage of moisture. (A. 26.)

Weibel Process. An electrical fusion process applied to sheet metal. The sheets are flanged at the edges to be joined, the depth of flanges being about $2\frac{1}{2}$ times the thickness of the sheet, and the angle through which the edge of the sheet is bent to form the flange is 100°, so that when the two flanged sheets are placed together there is an included angle between the flanges of 20°. The underside of the joint is coated with a suitable flux and the sheets are clamped in position. The inclined carbon electrodes are placed one on either side of the flanged edges, and the tool is drawn slowly along the joint towards the operator. The heat produced by the passage of the current through the electrode tips and the metal of the work melts the parent metal, thus welding the edges together. As the weld proceeds, the temperature of the electrode tips increases, so that the speed of movement of the tool must also increase in order to avoid excessive heating. (H. 51.)

Weiberg Magnesite Core - Moulding Process. The process uses moulding material consisting of silver sand and magnesite with a small addition of binding materials in the form of magnesium chloride wash and bentonite. The resulting mixture dries in a short time to a hard mass of high gas permeability. (K. 6.)

Weight. The force of attraction of the earth on a given mass is the weight of that mass. Usually measured in the same units as mass.

Weight, British Units of. (See Appendix II.)

Weight, Metric Units of. (See Appendix II.)

Weight of Bars. (See Appendix I.)

Weights. (See Appendix II.)

Weld. A localized coalescence of metal wherein coalescence is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of *filler metal*.

Weld Bead. The built-up portion of a fusion weld, formed either from the filler metal or from the melting of the parent metal. (A. 27.)

Weld Cracking Test. A test in which an experimental weld is prepared under controlled conditions of restraint and may be for the purpose of testing either the *parent metal* or the electrode. A considerable number and variety of these tests have been devised, and are listed in alphabetical order. (L. 17.)

Weld Decay. (See INTERCRYSTALLINE CORROSION.)
Weld Decay Test. (See HATFIELD INTERCRYSTALLINE CORROSION TEST.)
Weld Line. (See BOND.)
Weld Metal. That portion of a weld which has been melted during *welding*.
Weld Nugget. The ellipsoidal melted area of a spot weld.
Weld Time. In single-impulse welding and flash welding, the time that welding current is applied to the work in making a weld.
Weldability. The resistance to cracking of the heat-affected material under given conditions of restraint. (L. 17.)
Welding. In general, this may be described as a process of uniting two pieces of metal or alloy by raising the temperature of the surfaces of the metal or alloy to be joined to a plastic or molten condition with or without the application of pressure and with or without the use of added metal. This definition excludes the more recently developed method of *cold welding* in which pressure alone is used. Cold welding, however, has a limited application and is used principally for aluminium and its alloys and not for steel. There are numerous methods of welding among which the following are some of the more important: *Argon-Arc, Argonaut, atomic hydrogen arc, carbon arc, flash-butt, forge, fusion, gas, metal-arc, oxy-acetylene, oxy-hydrogen, oxy-propane, pressure, projection, resistance, seam, spot, stitch, stud, submerged-arc*.
Welding Arc Voltage. The sum of the true arc voltage and the voltage drop in the electrode.
Welding Bell. (See BUTT-WELDING PROCESS FOR THE PRODUCTION OF TUBES.)
Welding Current. The current flowing through the welding circuit during the making of a weld. In resistance welding, the current used during preweld and postweld intervals is excluded. (A. 37.)
Welding Electrode. (See ELECTRODE.)
Welding Force. (See ELECTRODE FORCE and PLATEN FORCE.)
Welding Ground. (See WORK LEAD.)
Welding Heat. The temperature at which the union of the metals is effected in a welding operation.
Welding Leads. The work lead and electrode lead of an arc welding circuit. (A. 37.)
Welding Rod. *Filler metal*, in wire or rod form used in brazing and in certain welding processes where the electrode does not itself furnish the filler metal.
Welding Scale. The scale formed in a welding operation. It consists of a mixture of flux and the oxides of the metals being welded.
Welding Stress. The stress resulting from localized heating and cooling of metal during welding. (A. 26.)
Welding Test. (See WELD CRACKING TEST.)
Welding Torch. A device used in gas welding or torch brazing for mixing and controlling the flow of gases. (A. 37.)
Welding Wheel. (See ELECTRODE.)
Welding Wire. Wire, usually of steel, employed in oxy-acetylene or electric arc welding.
Weldment. An assembly whose component parts are joined by welding. (A. 37.)
Weldomat Process. An automatic arc welding process, which employs high speed electrodes of large diameters. The method is based on the ability of a heavily-coated mineral-type electrode to produce a sound weld while the edge of the coating is in contact with the metal to be welded. A special type of holder, consisting essentially of an arm pivoted on a pedestal, is used to hold the electrode in the correct position relative to the work. Two such units are placed one behind the other, the second unit being so arranged that it automatically begins welding immediately the first electrode has been deposited. (W. 19.)
Well. (See CUPOLA.)
Wellman Tilting Furnace. A modification of the *open hearth furnace* in which the *ports* move with the hearth when the latter is tilted, and a pouring spout replaces the tap hole.
Wertheim Effect. (See) MAGNETOSTRICTION.
Westinghouse Creep Rupture Testing Machine. A machine for determining creep-rupture strength, which employs a motor-driven screw for applying the load, instead of the conventional lever arm and weights, and incorporates automatic recording equipment for tracing an individual creep curve for each specimen. (M. 70.)
Westinghouse Fatigue Testing Machine. An electromagnetic bending fatigue machine for testing high temperature alloys at temperatures of 650° and above. The specimen is a fixed, non-rotating, cantilever which is vibrated in bending at a frequency of 120 cycles per second, and is maintained at the desired testing temperature by means of a bell-type resistance furnace. (T. 40.)
Westinghouse Jet Metal Test. A test method for high strength heat resistant alloys required for jet engines. Discs 1 ft. in diam., and 1 in. thick are rotated at 35,000 r.p.m. while being heated to 760° C. This is continued until the disc flies apart. (A. 63.)

Westinghouse Thickness Gauge. An X-ray thickness gauge for use in rolling mills which permits continuous measurement of roll pressure and of sheet and strip thickness, and does not require contact with the material being gauged. The gauge employs two X-ray sources, whose radiations penetrate a standard and the test sheet in alternating cycles. The amount of radiation absorbed will vary with the thickness of the material. The X-ray energy not absorbed is picked up by the fluorescent screen unit in the photomultiplier which receives first the radiation penetrating the standard and then that penetrating the sheet. (I. 34.)

Weston Moulding Sand Process. A process for chemically coating foundry sands with a microthin film of carbon resin for refractory and bonding properties. The chemical is a viscous liquid containing an almost pure carbon resin, a solvent, and water. The product is claimed to have better sand flowability than other synthetic sands, and there is a consequent reduction by roughly 50% of the conventional additions of clay and water, and the complete elimination of coal dust. (T. 53.)

Westphal. A type of weighing balance used for the determination of the specific gravity of liquids and solids.

Wet Analysis. A term frequently applied to chemical analysis as opposed to *spectrographic*, i.e. *dry analysis.*

Wet Assay. The determination of the metal content of an ore by chemical analysis which involves taking the ore into solution.

Wet Bulb Temperature. The temperature shown on a thermometer when the bulb is covered with a wet cotton wick. The temperature indicated is lower than that shown by the *dry bulb thermometer*, in proportion to the amount of evaporation of moisture from the cotton. From the temperature recorded by both the wet and dry bulb thermometers the relative humidity of the atmosphere may be obtained.

Wet Drawn Wire. (*Lacquer Drawn Wire.*) Wire which has been drawn through a liquid lubricant with the object of producing a bright polished surface.

Wet Metallurgy. (See HYDROMETALLURGY.)

Wet Puddling. *Puddling* on a hearth rich in iron oxides and in which the metal is brought to the molten state in order to assist the removal of impurities by intimate reaction with the molten *fettling*.

Wetherill Vacuum Casting Process. In this process, the mould, arranged for bottom feeding, is placed inside a vacuum bell; the bottom of the mould is connected by a tube to a ladle containing the molten metal, which is sucked into the mould cavity when the vacuum is formed. It is claimed that this process gives increased yield of good castings because of exact control over pouring conditions; and a reduction in porosity and slag inclusions. (P. 22.)

Wettability. The extent to which a solid is wetted by a liquid.

Wetting. Intimate contact between a liquid and a solid.

Wetting Agents. In *pickling*, these consist of organic compounds added to the bath for the purpose of reducing interfacial tension between the pickling solution and the steel and thus facilitate wetting and rinsing operations. (S. 65.)

Wetting Effect. (See LIQUOSTRICTION.)

Wetting Test for Solders. Twisted pairs of wires are immersed vertically in a bath of molten solder and the height of capillary rise between the wires in 15 sec. is observed. This height depends on temperature and composition of the alloy, diameter and thermal conductivity of the wires, their twist and cleanliness, nature of the flux, and time of immersion. By maintaining other factors constant, variation in wettability as a function of any one factor can be readily determined. (B. 35.)

Wheatstone Bridge. A divided electrical circuit used for the measurement of electrical resistance.

Wheel Swarf. In general, a mixture of siliceous sand and finely divided metal produced during a grinding operation from the mutual abrasion between the surface of the grinding wheel and the metal being ground. The wheel swarf used to form an air-tight seal in, for example, the *cementation process*, consists of a mixture of fine particles of steel with the siliceous sand from the grindstone, which on heating forms a vitreous and impermeable silicate of iron.

Wheelabrator Process. A method of descaling in which metal abrasive, fed by gravity into the centre of a bladed wheel running at about 2000 r.p.m., is thrown against the work by the centrifugal force of the wheel which is capable of throwing up to 30 tons of abrasive per hour.

Whelps. Firebricks of a certain standard size.

Whipple Indicator. A *resistance pyrometer*, in which the increase in resistance of the bulb, i.e. platinum wire, due to heat, is measured by the *Wheatstone bridge* method. It can be used for the measurement of temperatures between $-10°$ to $1200°$ C.

Whirl. A device for straightening wire. It employs a series of staggered rotating dies which bend the wire successively in opposite directions.

Whirl Gate. A *gate* or *sprue* arranged to introduce metal into the *mould* tangentially, thereby imparting a swirling motion, which separates the slag and oxide from the metal by means of centrifugal force.

Whistler. An American term for a small vent opening from isolated mould cavities, usually high points, to allow trapped gases to escape quickly.

White Annealing. (*a*) A process of heating pickled steel to a temperature of about 600° C. for the purpose of eliminating the hydrogen which has entered the steel during the pickling operation, and thus to remove any tendency to hydrogen embrittlement. (*b*) A treatment for the production of *bright annealed wire*, in which it is dry drawn without any subsequent heat treatment.

White Finished Sheet. Hot rolled, pickled and annealed steel sheet which has been submitted to a final pickling treatment to remove the scale.

White Gold. Gold alloyed with nickel, palladium or zinc.

White Heart Castings. (See CAST IRON.)

White Iron. (See CAST IRON.)

White Iron Pyrites. (See MARCASITE.)

White Metals. (*Anti-friction Metals.*) (*a*) A general term covering alloys that are based on tin, lead or antimony, such as *bearing*, *type*, and *Babbitt metals*. (*b*) A copper matte of about 77% copper obtained from the smelting of sulphide copper ores. (A. 27.)

White Nickel. (See CHLOANTHITE.)

White Olivine. (See FORSTERITE.)

White Pickling. The pickling operation carried out on a close annealed sheet prior to *tinning* or *terne coating*.

White Print. A *shop print* made on *diazo* paper.

White Slag. Slag in which the carbon present has been converted to calcium carbide thus rendering it white in colour. It is used in the basic electric arc process.

White-Souther Fatigue Testing Machine. A machine for the application of repeated bending based on the principle of the *Wöhler machine*. Two specimens are employed but usually one specimen only is tested at a time, loading being applied by a spring or dead weight. The test piece is reduced in section by means of a fillet to ensure that fracture takes place away from the chuck. (G. 36.)

White to Edge Finish. (See GAS COOLED, SILVER FINISH.)

White Vitriol. White sulphate of zinc.

Whitening. (*a*) Coating metals with a thin film of another metal, such as tin, silver or nickel by means of immersion. (*b*) (See WHITING.)

Whiting. A very fine preparation of *chalk*.

Whitwell Stove. A *hot blast stove* built of refractory bricks and working on a regenerative system.

Whitworth Gauge. A gauge in which the gauge number is equivalent to the thickness of sheet or diameter of wire in thousandths of an inch.

W.I. Abbreviation for *wrought iron*.

Wiberg-Soderfors Process. In this process iron ore is charged at the top of a shaft furnace into a preheating zone in which it is heated to about 1010° C. by blowing in air to burn the gases rising from the lower zones; any sulphur present is completely removed and Fe_3O_4 is oxidized to Fe_2O_3. It then falls through a pre-reduction zone in which it is reduced to *wustite*, the reaction being endothermic and the temperature falling to about 845° C. In the lowest zone of the shaft the wustite is reduced to sponge iron by a rising current of gas consisting of about 70% carbon monoxide and 26% hydrogen. The heat of reaction together with the heat introduced with the gases raises the temperature again to about 1010° C. (K. 5.)

Wicket. (*a*) A small door within the framework of an *open hearth furnace* which gives access for the taking of *spoon samples*, for inspection and for pyrometric control. (*b*) In a *blast furnace*, see TUYERE CAP.

Widmanstätten Structure. A structure resulting when steels are cooled at a critical rate from extremely high temperatures. It consists of ferrite and pearlite and has a characteristic cross-hatched appearance, due to the ferrite having been selectively cooled along certain crystallographic planes instead of at the grain boundaries.

Wiedemann Effect. (See MAGNETOSTRICTION.)

Wien's Displacement Law. When the temperature of a radiating black body increases, the wave-length corresponding to maximum energy decreases in such a way that the product of the absolute temperature and wave-length is constant.

Wild Barfield Furnace. An electric furnace intended principally for *heat treatment*, and *nitriding* operations.

Wild Coal. (See BLACKBAND IRONSTONE.)

Wild Steel. Steel which has not been completely deoxidized and reacts violently after casting, due to liberation of gases on cooling.

Wiles' Process. (*Hollow Electrode Furnace.*) A method of reducing iron ores in which the electric furnace is fitted with two or more hollow electrodes, through which the finely divided ore intimately mixed with reducing materials is introduced. (N. 7.)

Wilhelmy's Law. The velocity of a chemical reaction at any instant is proportional to the concentrations of the reacting substances.

Williams Continuous Process. A casting process which employs a water-cooled vertical rectangular mould of brass or copper of up to ½ in. in thickness. The mould is long enough to permit the solidification of only sufficient ingot skin within the mould to prevent the pressure of the molten metal within from bursting the skin as the piece emerges from the bottom of the mould. The completion of solidification is controlled by water sprayed directly against the ingot surface. Pairs of rolls below the mould compress the descending ingot and squeeze out the shrinkage cavity. (W. 51.)

Williams Core. A *core* placed in a blind *riser* so that the metal within the riser is subject to atmospheric pressure, thereby eliminating establishment of partial vacuum within the riser as the metal begins to solidify, the core permitting the ingress of air, thus promoting free flow of metal to feed the casting. (A. 26.)

Williams Riser. An atmospheric pressure head used in sand moulds.

Williams Feeder Head. (*Atmospheric Pressure Head.*) A type of head which uses a pencil core to form a hot spot and allows the influence of atmospheric pressure to reach the molten metal in the centre of the head after the initial skin on the rest of the head has frozen.

Wilson Hardenability Test. The test specimen is 1½ in. in diam. by 11 in. long, and is provided with seven thermocouple wells drilled radially through the centre of the bar to a depth of $\frac{1}{16}$ in. from the opposite side of the bar. Water at room temperature is used to quench one end of the hardenability bar and is directed vertically from a ½ in. diam. jet orifice with a velocity corresponding to a free jet height of 3½ in. The specimen is supported from the top of the heating furnace which practically surrounds it during the test. (W. 62.)

Wind. The air blast in a *blast furnace* or *cupola*.

Wind Box. (*a*) The space at the bottom of a *Bessemer converter* from which the air blast passes through the tuyeres into the metal bath. (See Fig. 1.) (*b*) (See CUPOLA) (Fig. 4).

Wind Furnace. An old type of furnace which relied on a natural draught without the use of forced air blast.

Winding Strips. A term used in the foundry for parallel straight-edges employed for testing large working faces.

Window. The space in the housing of a *rolling mill* which holds the roll bearings.

Windrow. A long heap or pile of foundry sand on the floor ready for cutting, or for re-use. (U.S.A.)

Winged Ingots. Ingots having a section consisting of three squares joined together by a triangle. The three wings are cut off, whilst the central portion is discarded. (F. 15.)

Wipe. The device for removing excess spelter from galvanized steel wire.

Wiped Galvanized Wire. Electro or hot galvanized wire which is wiped whilst the zinc is still molten.

Wiped Joint. A joint made in a lead pipe by means of *plumber's solder* (lead 66·66%, tin 33·33%) an alloy having a long plastic or pasty range, of nearly 70° C.

Wiping Solder. Soft or *plumber's solder*.

Wire. Round metal filaments produced in pieces of considerable length by cold drawing *wire rod*. (See WIRE DRAWING.)

Wire Drawer's Plate. A tool containing a series of tapered holes through which wire is drawn.

Wire Drawing. Reducing the diameter of wire by passing it through dies or tapered holes in a *wire drawer's plate*. In modern practice the wire is drawn through tungsten carbide dies in continuous machines. Ferrous metals work-harden fairly rapidly in drawing, the extent depending upon their carbon content and the degree of alloying. The bulk of steel wire regularly drawn in the trade varies from about 0·1% to 0·8% carbon content, but quantities are drawn containing up to 1·4% carbon. These high carbon wires work-harden very rapidly and can be cold drawn to a tensile strength of 200 tons per sq. in.; they are usually employed for springs, a typical wire for this purpose containing about 0·7% carbon, the wire having undergone a 90% reduction in area from the hot-rolled rod. (See also PIANO WIRE.) (I. 55.)

Wire Flattening. A process whereby narrow flat strip is produced by cold rolling round wire between plain parallel rolls. (U. 1.)

Wire-Flaw-Kawimeter. A non-destructive testing instrument for detecting both internal and external flaws in wire. (M. 117.)

Wire Life Test Method. A method for evaluating electric heating wire which makes use of a 0·025 in. diam. wire,

heated electrically for cycles of 2 min. on and 2 min. off. The test is continued until either the wire fails or the electric resistance increases by 10%. The test is used for rapid evaluation of alloys, and various metal surface treatments, for high temperature oxidation. (B. 81.)

Wire Penetrameters. (See PENETRAMETERS.)

Wire Rod. A semi-finished product intended for the production of wire by *cold drawing.*

Wire Sensitivity. (See PENETRAMETERS.)

Wisdom Ribbon. A steel ribbon devised to hold the *Söderberg electrode.*

Witherite. A mineral consisting essentially of barium carbonate. It is found in Cumberland and is used in case-hardening compounds.

Witter Process. A method of shell forging in which billet steel is upset, forged or pressed to form the pierced blank. This blank is conveyed to a loading station of the finishing mill where it enters the breakdown pass of the humped rolls with a smoothly machined mandrel inserted in the cavity of the pierced blank. The mandrel is kept in the blank by pressure from a pushing cylinder during the breakdown, elongating, and cross-rolling operations. On elongating, the metal wraps tightly on the mandrel as it passes through the humped rolls, thus producing a smooth and uniform cavity in the shell forging. After leaving the rolls, the forging is sized with mandrel still inserted and then the mandrel is automatically stripped, leaving the shell forging completed and ready for machining operations elsewhere. (C. 59.)

WO_3. Chemical formula for tungstic oxide.

Wobbler. The approximately rectangular prolongation of the neck of the roll by which it is driven. (See ROLLING MILLS.)

Wöhler Fatigue Testing Machine. A machine for the application of repeated bending stresses. Two specimens forming extensions to a rotating shaft are loaded by means of springs. Sometimes, one end of the specimen is held rigid while the cyclical variation in fibre stress is the same as in the rotating bar test. The other end of the specimen is then loaded by means of a helical spring which is clamped into a carrier made to rotate in a bearing. The end of the specimen thus describes a circle, the radius of which is the deflection of the specimen due to the applied load. (G. 36.)

Wöhler, Friedrich. (1800–82.) A German chemist, who isolated aluminium in 1827 and beryllium in 1828.

Wöhler Torsional Fatigue Machine. A machine for applying repeated torsional stresses. A specimen running freely in bearings has attached to its ends levers, one of which is given angular oscillations by a variable crank, the other double lever being connected to stops held in position by means of calibrated springs. The throw of the crank causes one or both parts of the double lever to lift off their stops against the springs. By using one or both of the levers, and adjusting the springs, the machine is made to give any torsional stress variation. (G. 36.)

Wolfram. An alternative name for *tungsten.*

Wolframite. A tungsten ore consisting of a tungstate of iron and manganese $(Mn,Fe)WO_4$. It is one of the two most important commercial ores of tungsten. (See also SCHEELITE.)

Wolf's Oven. (*High Bloomery.*) An early type furnace used for the direct production of *malleable iron.*

Wollaston Process. A process of drawing extremely fine wire in which a partially drawn wire is fitted into a tube of another ductile metal. The composite is then rolled and drawn to the required size after which the covering metal is dissolved away. The method is frequently applied to the drawing of noble metals, such as gold.

Wolpert Hardness Tester. (See DIA-TESTOR.)

Wood Tin. (See TIN.)

Wood's Alloys. Fusible alloys of variable composition consisting of bismuth, tin, and lead, and usually containing cadmium. A typical alloy, containing 50% bismuth, 25% lead, 12·5% tin and 12·5% cadmium, melts at 70° C.

Woody Fracture. (See FRACTURE.)

Wool Fat. (See DEGRAS.)

Wootz. A term used for *Indian steel,* manufactured from *wrought iron,* which was made in a native furnace (India) in small crucibles of refractory clay, in each of which about a pound of metal was placed with a certain proportion of finely chopped wood. The crucibles were then covered with leaves and wetted clay and placed in the sun to dry, and when hardened, 20 to 24 of the crucibles were built in an arched form, on the bottom of a small *blast furnace,* blown by bellows, and strongly heated for two or three hours. The furnace was then allowed to cool, the crucibles taken out and broken, the steel having melted down to a rounded button at the bottom of each pot. Probably in order that it might be completely melted, the steel was overcarburized, and before drawing out into bars the buttons were heated for several hours in a charcoal fire, blown by bellows, to a temperature

not much below melting point, so that the metal might be partially decarburized. (H. 17.)

Work. The result of a force acting against resistance to produce motion in a body. Work is measured by the product of the force acting and the distance moved through against the resistance. Units of work are defined under *erg* and *foot pound*.

Work Hardening. The increase in hardness and strength produced by deformation and mechanical working. (See COLD WORKING.)

Work Lead. (*Welding Ground.*) The electric conductor between the source of arc-welding current and the work. (A. 37.)

Work Surface. In machining the term refers to the surface to be machined.

Workable Moisture. That range of moisture content within which the sand fills, rams, draws and dries to a satisfactory *mould*, and within which the sand does not dry out too fast to mould and patch. (A. 26.)

Working Edge. The edge surface of a piece of material that has been planed straight and square with the *working face*. (A. 26.)

Working Face. The surface of a piece of material that has been planed true and that is to be used as a basis for the dressing of all other surfaces. (A. 26.)

Working Rolls. (See ROLLING MILLS.)

Working Stress. The actual stress which a part is designed to withstand in practice.

Worm Marking. (See RAT TAILING.)

Worming. (See CRAZING.)

Worms. (See PIOBERT EFFECT.)

Wortle. (*a*) A workshop name now seldom used for tungsten. (*b*) Tool steels containing tungsten. (*c*) An alternative name for a *wire drawer's plate* made from a tungsten tool steel.

Woxen Microhardness Tester. An instrument which incorporates both the impression difference due to various initial loads and test loads ranging from a few g. up to 1 kg. and the corresponding impression diagonal or diameter measured in one test. It is possible to work out by means of equations or nomograms *Vickers* and *Woxen numbers*, and at the same time determine the cold working capacity not only for metals of any hardness, but also for certain crystals and for very thin, hard surface layers. (W. 73.)

Woxen Number. (H_W.) In a hardness test the major load divided by the indentation area, that is, the area of that part of the indenter which after removal of the major load is situated below the original level of the test piece.

W.Q. Abbreviation for water quenched.

Wrapping Test. A test for wire; the wire is wrapped round a *mandrel* of specified diameter, usually that of the wire under test, for a specified number of times. A usual specification is that the wire should be wrapped eight times and unwrapped seven times without fracture.

Wrinkling. The term applied in deep drawing operations to the formation of wrinkles or corrugations in that part of a blank which has not passed over the radius of the drawing die. (Cf. PUCKERING.)

Wrought. The broad term applied to forged, rolled or drawn products.

Wrought Iron. A commercial iron which may be produced by many different processes, as for example, *puddling*, *Walloon*, *Lancashire open hearth*, or by a modern variant of any of these. The chief characteristic of wrought iron is that the temperatures employed in its production are too low to render it fluid and its condition is never more than pasty or semi-fused. Hence it contains an appreciable quantity of *slag*. On hammering, the metal granules are elongated and more or less welded together whilst much of the slag is squeezed out, but some remains intermingled with the iron in thread-like form, thus giving the characteristic fibrous structure of wrought iron.

Wuerful Hardenability Test. (*McCleary and Wuerful Test.*) This method makes use of the Wuerful bomb, which is a cone-shaped piece of steel $3\frac{5}{8}$ in. long, tapering from 2 in. to $\frac{1}{2}$ in. in diam. with a $\frac{5}{16}$ in. diam. hole down the centre provided with a screwed plug. The test piece is a plain cylinder $3\frac{1}{2}$ in. long, slightly less than $\frac{5}{16}$ in. in diam. A small amount of a low melting point alloy, such as *Wood's metal* is put in and the bomb is warmed to melt it; the test piece is inserted and the plug screwed in. The alloy provides the thermal contact between the bomb and test piece. The assembly is heated to the temperature suited to the steel under test and quenched in water. After warming the bomb to melt the alloy, the specimen is removed and hardness readings are taken along its length and a curve is plotted for hardness against the distance from the small end. (M. 4.)

Wulfenite. Molybdate of lead, $PbMoO_4$, occurring commonly as yellow orthorhombic crystals in veins with other lead ores. Named after an Austrian mineralogist, Von Wulfen.

Wust and Bardenheuer Apparatus. A dynamic hardness testing instrument.

It employs a magnetic release which allows a tup, with a 5 mm. ball indenter, and weighing 1058 g. to fall vertically on to a clamped test piece.

Wustite. (FeO). Ferrous oxide.

W.W.G. Abbreviation for Warrington Wire Gauge.

X

X. An alternative chemical symbol for *xenon*.

x. A symbol for *mol fraction*.

X-ray Analysis. (See X-RAY CRYSTALLOGRAPHY.)

X-ray Crystallography. (*X-ray Analysis.*) Max von Laue in 1921 showed that the planes of atoms in crystals act as a diffraction grating to X-rays, which are scattered by them and provide an accurate means of determining the details of the internal atomic structure. These X-ray photographs of metals provide information which in many cases cannot be obtained by ordinary microscopic methods. The lines produced by each element, or phase, are characteristic and their general pattern enables the crystalline structure to be identified. The scale of the pattern can be used to determine accurately the size of the unit cell and therefore the distance apart of the individual atoms; and from the relative intensity of the lines can be deduced the distribution throughout the unit cell of the various types of atoms in an alloy, or the degree of preferred orientation in the material. In addition, the sharpness of the lines provides information on both the state of strain and the grain size of the material.

X-ray Determination of Particle Size. The X-ray method of measuring particle size as applicable to particles from approximately 0·00001 cm. in diam. down to the smallest which have a crystalline structure. These particles give rise to diffraction lines broader than those ordinarily found in the powder photograph. Measurements of particle size are based on some theoretical formula which connects the breadths of the diffraction lines with the size of the particles. (C. 4.)

X-ray Diffraction Interplanar Scale. (*Self Printing.*) An instrument which prints an interplanar scale in *Ångström units* on one half of an X-ray diffraction picture, thus enabling one to look at a diffraction picture and record directly values of interplanar spacings without measuring the diameter of the X-ray diffraction rings and solving the *Bragg equation*. (B. 90.)

X-ray Fluoroscopy. This method, which in many respects is analogous to normal emission spectroscopy, is claimed to be most suitable for determining elements present in relatively high amounts, whilst using normal emission spectroscopy for minor components. A flat sample is held beneath an X-ray tube window where it is subjected to high intensity X-rays, the tube being operated at usually 50 kV and 50 milliamp. X-rays striking the sample cause energy transitions within atoms, causing emission by the sample of radiation composed of X-rays having wave-lengths characteristic of the specific elements present. A small sector of this radiation, emitted in the horizontal plane, passes through a short collimator and strikes a mica crystal, through which it passes and is diffracted by the crystal planes to give focusing at angles corresponding to those given by the *Bragg equation*: $n \lambda = 2d \sin \theta$ where n is the order of diffraction (1st order is used), λ is the wave-length of the radiation, d is the distance between the diffracting planes of the crystal, θ is the angle between the incident radiation and the diffracting crystal planes. The unit uses a bent mica crystal that has proved capable of separating radiation from elements that emit X-ray lines of nearly the same wave-length. The instrument incorporates stabilizing devices to insure a constant intensity of X-rays to excite the sample. The intensity of a characteristic line is measured by a *Geiger counter*, connected to a counting circuit and timer, from which the time required for a pre-set number of pulses or counts is obtained. An automatic chart recorder can be used to produce a plot giving the angle and intensity for characteristic lines as the goniometer moves the counter tube through desired limits for the angle θ. This plot, in itself, represents a qualitative analysis. For quantitative analysis, the goniometer is set at the angle representing the maximum intensity of the line characteristic of the element to be determined, the composition being established from line intensity. (B. 92a.)

X-ray Gauging. A method for the automatic gauging of thickness without physically contacting the material being measured. It constitutes a comparison process in which the X-ray penetration through the material being measured, e.g. a propeller blade, is compared with the penetration of an X-ray beam of equal strength through a metal sample of known thickness. For this purpose, two X-ray beams approximately $\frac{1}{16}$ in. in diam. pass through the standard

sample and the propeller blade respectively. Cadmium sulphide crystal detectors, placed inside the propeller blade and next to the reference sample respectively, are employed to detect the variation in X-ray intensity. The amplified detector outputs are then applied to a bridge circuit to produce a deviation reading. (E. 76.)

X-ray Micrography. A term applied to any X-ray picture in which viewing by a microscope or photo micrography is used to bring out metallurgical information. (B. 11.)

X-ray Stress Measurements. A method of measuring residual stress which consists in making a number of measurements by *back reflection* technique of a particular interplanar spacing at a point on the surface of a metal specimen, calculating strains from these spacing values, relating these strains to the principal strains in the metal surface by the elastic theory for a homogeneous isotropic body, and then calculating the principal stresses from the principal strains. (T. 49.)

X-ray Thickness Gauge. A gauge for detecting changes in the thickness of hot steel strip as it is rolled. An X-ray tube emits two beams, a reference beam passing through a standard wedge on to a phosphorescent screen in front of a photoelectric detector, and a measuring beam passing through a measuring wedge and the steel strip to a second detector. By adjustment of the positions of the wedges, the absorption of the beams can be balanced to suit the correct thickness of the strip; when off-gauge material passes through the measuring beam the detector outputs are thrown out of balance and the difference is shown on an indicator. (C. 27.)

X-ray Tube. An evacuated tube in which X-rays are emitted from a metal target, placed obliquely opposite to an incandescent cathode, whose rays impinge on the target.

X-rays. (*Röntgen Rays.*) These rays, first detected by W. C. Röntgen in 1895, are a form of electromagnetic radiation similar to ordinary white light, but differing by their wave-length characteristics. The wave-length of X-rays is much shorter than that of visible light, which fact enables radiation to penetrate materials opaque to light. This phenomenon is used in practice for *radiography*. The shorter the wave-length the more readily they penetrate substances whilst the absorption of X-rays depends on the density of the material and its thickness. The definition of X-rays is usually applied to electromagnetic radiations produced in high voltage equipment as opposed to those produced by radioactive material. (See GAMMA RAYS.) The minimum wave-length produced by an X-ray tube depends on the voltage applied across it according to the formula: Voltage across

$$\text{tube} = \frac{12{,}400}{\text{wave-length in ångström units.}}$$

Hence, the greater the penetration required, the higher the voltage that must be applied to the X-ray unit. X-ray tubes have been designed and are in common use with applied voltages from 30 kV up to 2000 kV, whilst for shorter wave-lengths, the apparatus is of a different design, called a *Betatron.* A further important use of X-rays is in *X-ray crystallography.* X-rays are also used for diagnostic radiography in medicine and for radiotherapy. (N. 16a.)

Xe. Chemical symbol for *xenon.*

Xenon. (*X* or *Xe.*) *Atomic weight* 131·3. A very rare and inert gas.

Xeroradiography. A rapid, all electric method of obtaining permanent *X-ray* images which employs an electrically conductive metal plate, often of aluminium, in place of the usual film. This plate, which can be used repeatedly, is sensitized to X-rays by uniformly spraying its surface with an electrostatic charge. On exposure to X-rays the coating becomes conductive and discharges its electrostatic charge into the backing metal. The rate of loss of charge is a direct function of the intensity of exposure. The latent electrical image is made visible by dusting a dry powder, having suitable *tribo-electric* properties, over the plate when the powder adheres to regions which remain charged. The image may be viewed immediately, or a permanent print may be made in a few seconds. In the latter case, a sheet of ordinary paper is placed over the powder which has been previously compounded to include a resin content, and the powder transferred to the paper by the charging machine. Radiant heat is then applied and the powder fuses on to the paper. (M. 17.)

Y

Y. Chemical symbol for *yttrium.*

Y-Mill. A type of reversing cold strip mill consisting of seven rolls in Y-formation. There is a V-shaped group of five rolls directly above the lower work roll. In a typical example, the bottom roll of the five is a 3¼ in. diam.

work roll, and in contact with this, on each side at 45° from the vertical, is an intermediate roll 6¼ in. diam., each of which is backed by a 17¾ in. diam. roll. The work and the backing rolls below the strip are 8¼ and 19¾ in. in diam. respectively. The lower work roll and the two upper intermediate rolls are driven by a 600-h.p. motor. The mill is designed to roll strip up to 17 in. wide at delivery speeds of 600 to 1200 ft./min. (M. 154.)

Yardeny-ATF Remote Control System. An electromechanical device by means of which an operator is able to control a motor-driven mechanism at a remote location. (K. 9.)

Yarranton, Andrew. (1616–84.) An English engineer and agriculturist who in 1665 was commissioned to go to Saxony to inquire into the process of tinplate manufacture. He gave an account of his visit in "*England's Improvement,*" published in 1681. (E. 85.)

Yb. Chemical symbol for *ytterbium*.

Yield. The ratio of the weight of the finished product to that of the raw material, i.e. in forging, the quotient obtained by dividing the *net weight* or *shape weight* by the gross weight; in rolled products, the weight of bar divided by the ingot weight.

Yield Point. The *stress* in a material at which there occurs a marked increase in *strain* without an increase in stress. There are two methods of determining yield point, (1) *Drop of the Beam Method*, in which the load is applied to the specimen at any convenient speed of testing up to one half the specified yield point or up to one quarter the specified tensile strength, whichever is smaller, and the operator keeps the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of load stops, but the operator runs the poise a trifle beyond the balance position, and the beam of the machine drops for a brief but appreciable interval of time. In a machine fitted with a self-indicating load-measuring device, there is a sudden halt of the load-indicating pointer corresponding to the drop of the beam. The load at the *Halt in the Gauge* or the drop of the beam is recorded and the corresponding stress is taken as the yield point. (2) *Total Strain Method Using Dividers*. In this method, frequently called the *Dividers Method*, the elongation on the specimen is observed either with the aid of an *extensometer* or by means of a pair of dividers, the points of which are fitted into the *pop marks*, the load at the instant when one of the points no longer fits into its mark being taken as the yield point.

Yield Stress. The stress (load divided by original area of cross-section of a test piece) at which elongation of the test piece first increases without increase of load. For materials which have a yield stress, it may be further defined as the stress at which a sudden visible increase occurs in the distances between the gauge points of the test piece when using dividers; or at which, when the load is increased at a moderately fast rate, there is a distinct drop of the testing machine lever, or, in indicating machines, hesitation in the movement of the indicating pointer. (B. 100.)

Yorkshire Iron. The term *Best Yorkshire* now indicates very high quality wrought iron without reference to its place of origin. Although the term originated from the district from which this grade of puddled wrought iron was first produced, no geographical significance or proprietary right is now implied by its use. (B.S. 858.)

Young's Modulus. (*Modulus of Elasticity*.) The ratio within the limits of elasticity of the stress to the corresponding strain, e.g. the load in tons per sq. in. divided by the deformation in fractions of an inch for each inch of the gauge length of the test piece. Examination of a large number of steels of widely varying composition shows that the modulus value is of the order of 13,400 tons per sq. in.

Yt. An alternative chemical symbol for *yttrium*.

Ytterbium. (*Yb.*) *Atomic weight* 173·04. *Specific gravity* 7·01. A rare earth element found in small quantities in most minerals containing *yttrium*.

Yttrotantalite. A mineral found in Ytterby in Sweden. As the name suggests it consists essentially of the oxides of tantalum and niobium, together with yttrium oxide. Oxides of *tungsten*, *erbium*, *uranium*, and other metals may be present, the balance being ferrous oxide.

Yttrium. (*Y* or *Yt.*) *Atomic weight* 88·92. *Specific gravity* 5·51. *Melting point* 1490° C. A rare earth element.

Yttrocerite. A massive, granular or earthy mineral, essentially fluoride of calcium, with the metals of the *yttrium* and *cerium* groups, commonly violet-blue in colour, and of rare occurrence.

Z 325 Hardness Tester. A low load hardness tester which works on the

Vickers principle with loads of 300 and 500 to 10,000 g. in increments of 500 g. The direct application of the load on the component without the use of levers is a special feature of this instrument. The speed of loading can be regulated by means of an oil brake. The evaluation is effected with a microscope with an enlargement of 100, 200 or 400 times.

Z Bars. (See STRUCTURAL SHAPES.)

Zac. Refractories containing zirconia made by electric melting and casting.

Zapffe Bar Bend Test. (See BAR BEND TEST.)

Zebra Induction Hardening of Steel Pipes. A method for hardening steel pipes in bands, to give alternately hard and tough sections. Both induction and flame hardening can be used, but the former method is preferable in view of the accuracy of the width heated and the temperature control. While being heated, the pipe passes in stages through the heating zone of the inductor acting from the outside. The ring section of the pipe is heated to a hardening temperature of 850° C. and then passes in the next stage to the quenching zone. The quenching water is supplied to the heated wall from the inside of the pipe by a suitably designed sprinkler. (S. 27.)

Zebra Roof. A method of construction using silica and basic brick in alternate courses. The former gives mechanical strength, and the latter resistance to chemical attack and protection for the silica. (S. 127.)

Zeeman Effect. The splitting up of a spectrum into several symmetrical parts when a source of light is submitted to a strong magnetic field.

Zees. Structural steel section designated by and similar in pattern to the letter "Z", specified by depth, width of flanges and weight per foot. (U.S.A.)

Zeiss Diritest Apparatus. A micro hardness tester in which the impression is made with a diamond pyramid which is attached to the beam of a balance and can be directly loaded with loose weights. The beam swings out and can be replaced by a micro-lens for examining and measuring the impression. (D. 34.)

Zeiss-Hanemann Microhardness Tester. (See HANEMANN MICROHARDNESS TESTER.)

Zeiss Hardness Tester. An instrument in which a diamond pyramid is set on the front lens of a microscope objective, so that observations can be made and also hardness indentation produced. The force required to produce the impression is read off by means of an auxiliary objective on the rear objective lens. (H. 14.)

Zeolite. A group of hydrated aluminium complex silicates having cation exchange properties. Such silicates may be either natural or synthetic.

Zeolite Softeners. Equipment containing *zeolite* for softening water.

Zephiran Chloride Etchant. A metallographic etching reagent composed of a mixture of alkyl-dimethyl-benzyl-ammonium chlorides, capable of differentiating between the tough and temper-brittle conditions of steels susceptible to *temper brittleness*. It makes a pronounced attack on the grain boundaries of steels embrittled either by slowly cooling from elevated temperatures or during tempering at intermediate temperatures, but does not affect steels in the tough condition or those not susceptible to temper brittleness. (C. 40.)

Zerener Process. A method of arc welding in which two carbon electrodes are used to draw the arc and to supply the welding heat.

Zero Spectrum. In revolving crystal and oscillating crystal patterns. A row of spots resulting from planes parallel to the axis of rotation or oscillation. Sometimes called zero line. (A. 27.)

Zetmeter. A measuring instrument for checking the dimensions of bores in dies It has a lifting table whereupon the die is placed and clamped. The slide of the vertical scale index is set to the value of the die bore diameter, whilst fine setting is performed by the screw on top of the main dial micrometer. When the die touches the lower tracer needle with the bottom edge of its cylindrical bore, the index slide is clamped to the die table. After lifting this table until the die contacts the upper needle, the bearing length can be immediately read on the main dial micrometer, with an accuracy of 0·01 mm., i e. 0·0004 in. respectively. (L. 55.)

Zieler Process. A method of estimating the number and size of *non-metallic inclusions*, in which sections cut from various parts of an ingot are examined microscopically and the number of inclusions per unit area is counted. (Z. 12.)

Zinc. (*Zn.*) *Atomic weight* 65·38. *Specific gravity* 7·133., *Melting point* 419·46° C. Zinc has a white colour with a bluish tinge. It has a bright metallic lustre on a freshly fractured surface and is capable of taking a high polish. The most important property of the metal is its high resistance to atmospheric corrosion and its major use is in surface protection of iron and steel sheet and

wire, by for example, *galvanizing*, *sherardizing*, spraying or painting with zinc pigmented paints.

Zinc Oxide. (*Chinese White, Zinc White.*) A white powder (ZnO) having a specific gravity of 5·78 and being insoluble in water; it is used as a pigment in paint and in chemical analysis.

Zincilate. A zinc coating applied to scale-free metal surfaces by brush, spray gun or dipping.

Zincote. A process of rust proofing steel and forming a paint bonding surface which consists of a one-minute dip or spray in a solution containing zinc nitrate, sodium bisulphate and sodium acetate followed by a rinse in dilute dichromate.

Zircon. Zirconium silicate of constitution $ZrO_2.SiO_2$ containing zirconium oxide 66·9%, silica 32·6%, with a minute proportion of titanium and iron oxides. A natural refractory occurring in large concentrated deposits as a sand in certain parts of the world, e.g. India, New South Wales. The term sand describes its physical nature rather than its chemical identity because it differs fundamentally from silica sand normally used in foundries, the basis of which is predominantly quartz of the chemical constitution SiO_2. Its high cost prohibits its general use as a moulding sand except when the most exacting requirements have to be met. (H. 58.)

Zirconia. (*ZrO_2.*) An oxide of *zirconium*. A valuable refractory having a high melting point, with low thermal conductivity; it has good thermal shock resistance, and low electrical resistivity. Its uses include furnace linings for extreme temperature-chemical reactions, and resistors for electric furnaces. (W. 44.)

Zirconium. (*Zr.*) *Atomic weight* 91·22. *Specific gravity* 6·49. *Melting point* 1845° C. The ultimate strength varies from about 15 to 40 tons/sq. in. according to the heat treatment and the condition of working. The metal can be supplied in the as-rolled condition or in the fully annealed state if in a small size. It is resistant to attack by most acids and bases. Zirconium acts as a deoxidizing element in steel and combines with the sulphur, thus reducing any tendency to red shortness. It is claimed that the presence of zirconium in high chromium steel castings increases their strength and renders them clean and free from porosity.

Zirconium Steel. (See ZIRCONIUM.)

Zn. Chemical symbol for *zinc*.

ZnO. *Zinc Oxide*.

Zobel Blowpipe Nozzle. A form of nozzle which is claimed to increase the speed of flame cutting. This special design produces an oxygen jet which emanates from the nozzle as a parallel stream, without sudden loss of energy by expansion from the nozzle pressure to the atmospheric pressure; this jet, therefore, retains its form over a considerable length of path. (D. 29a.)

Zone Axis. In a crystal, a line parallel to several crystal planes. The planes to which it is parallel form its zone. (A. 27.)

Zr. Chemical symbol for *zirconium*.

ZrO. Zirconium oxide. (See ZIRCONIA.)

Zwerg Brinell Hardness Tester. A small portable instrument consisting of two spring legs and designed to be clamped together with the work in a vice. Upon compressing the ball sleeve upon the specimen by drawing up the vice, the load thus applied is read off on a dial. The load ranges from 15 to 250, and 60 to 750 kg. according to the size of the instrument. (R. 25.)

Zyglo. A proprietary fluorescent compound for use in the *dye penetrant inspection* test. It is applied to non-magnetic materials for the detection of flaws.

NEW PROCESSES AND SUPPLEMENTARY DATA

Just before the ENCYCLOPÆDIA went to press, the Publishers received from the inventors, Messrs. Hüttenwerk Oberhausen AG, of Oberhausen, Rheinland, Federal Republic of Germany, some very full details of three processes which the firm has developed, and for which British patents have been granted.

The Publishers wish to express to Messrs. Hüttenwerk Oberhausen AG appreciation of their courtesy in responding to the request for this information, and of the trouble they took in supplying the detailed notes, in English, on which the following three entries (shown under the general heading "Oberhausen Processes") have been based.

The further entries on pages 473-477 present information gathered by the author since her manuscript was closed for press, from the sources shown in the References on page 478. This additional information is shown under the general heading "Supplementary Data".

OBERHAUSEN PROCESSES

OTwo Steel. A high quality basic Bessemer steel, having a nitrogen content of less than 0·008%, and low phosphorus. Its production involves bottom blowing with an oxygen enriched air blast. The additional oxygen is supplied to the molten iron during the blow in such a manner that the percentage of oxygen in the air blast is raised by *at least* 1% for each 1% of the accompanying elements burned. The percentage of oxygen in the air blast normally increases up to about 40% until the end of the blowing. This increase in gaseous oxygen may be supplemented by the addition of oxygen in solid form, as for example high grade iron ores or mill scale, in quantities adjusted to procure a final temperature which will ensure good casting properties of the steel. (British Patent No. 685,325.)

HOAG Desiliconization. A method for the refinement of molten pig iron prior to its use in either pneumatic processes or open hearth practice. This desiliconization is carried out in a vessel, e.g. a *mixer* or *ladle*, the refractory lining of which may be either acid or basic, according to the type of pig iron used. Very good results have been obtained with oxygen of 80% to 90% purity which is introduced beneath the surface of the bath by means of special type water-cooled copper nozzles at a relatively low pressure. The nozzles are immersed to a depth of about 300 to 500 mm. The efficiency of the oxygen is nearly 100%. During this treatment a substantial proportion of the silicon and manganese is oxidized, but the carbon and phosphorus are essentially unaffected. Owing to its low phosphorus content, the manganiferous slag thus obtained is a valuable raw material in the production of ferromanganese, or it can be used as a basis material in the production of ferrovanadium, if the pig iron contains more than 0·1% V. The temperature of the metal bath increases during the oxygen treatment, e.g. a refining time of 45 minutes resulted in an increase of temperature of 70° C. This process permits a wider choice in the selection of ores for the blast furnace. In the Bessemer practice it shortens the time of blow, yields a remarkably low nitrogen content of the steel, and results in a considerably enlarged converter capacity; in open hearth practice the use of pre-refined pig iron gives greatly improved output. (British Patent No. 705,954.)

Rotor Process. In this process, molten pig iron is refined in the Graef-Rotor, a horizontally mounted, cylindrical, rotating, refractory-lined vessel. The lining is either acid or basic according to the quality of iron used, the process being applicable to all types of pig iron. At each end of the Rotor is an opening. Through one end, water-cooled nozzles are led, some of which pass through the layer of slag and are submerged in the molten bath. Through these nozzles a blast of refining gas, preferably oxygen, is introduced at a comparatively low pressure into the molten bath. The opening at the other end of the Rotor extends into a smokebox and chimney flue. During the refining operation, the drum is revolved at a relatively low circumferential speed, e.g. less than 1 metre per second. It is remarkable that during the refining a simultaneous combustion of both carbon and phosphorus occurs. The carbon monoxide, evolved from the melt during the decarburization, is burned above the level of the bath with oxygen, introduced into the Rotor by other nozzles which are not submerged in the bath. The refining process can be so controlled that all reactions can be stopped at any desired carbon level. Hot metal can be produced as well as steel. The rotation of the vessel ensures that fresh portions of pig iron are constantly brought into the reaction zone, whilst the areas of the refractory lining, exposed to the action of the flames, are varied continuously, i.e. the lining is alternately heated by the flames and plunged below the surface of the metal. Thus the thermal efficiency is very high, as the total quantity of heat is transferred to the metal throughout the conversion. Considerable quantities of iron oxide in the form of ore or scale can be reduced by this process. (British Patent No. 726,368.) (See also I.70a.)

SUPPLEMENTARY DATA

Almulit. A type of silica brick for open hearth furnaces. The material has a fusion point of about 1805° C.

Alumincoat. A process for the protection of mild and low alloy steels against corrosion and high temperature oxidation. The steel is first thoroughly cleaned and then fluxed in a patent salt bath, after which it is dipped in molten aluminium or aluminium alloy. It is claimed that the aluminium penetrates the steel to a depth of 0·0015 to 0·002 in., and approximately 0·0005 to 0·001 in. of aluminium remains as a protective coating on the surface. The thickness of the coating may be determined by the material used and the duration of immersion.

Arc-Air Process. A metal-cutting process which depends on the melting of the metal with an electric arc, with the simultaneous removal of the metal by means of a high velocity air jet which is external and parallel to the electrode. The equipment consists of a torch with a concentric cable which carries both air and current. The electrode usually used is a combination of carbon and graphite either plain or copper coated. An air line from an ordinary air compressor and the cable from a d-c welding machine are both attached to the end of a concentric cable which carries both the air and the current to the torch. The lever at the bottom of the torch controls air flow. The electrode is held in a rotating head which allows it to be set at any angle, but maintains the air stream always directed at the proper location. (X. 24.)

Ardometer. An instrument for the rapid measurement of the temperature of hot-rolled strip steel. The surface temperature is measured by a thermocouple and the thermo-electric force fed into a galvanometer. The galvanometer deflects the light from a bulb on two photocells which operate in opposition. The potential difference of the two photocells is amplified and recorded. Signal lamps for GO and STOP within a predetermined temperature range can be provided. The result of the temperature reading is given within 0·5 seconds. (X. 22.)

Brymbo Desiliconization Practice. In this process, blast furnace iron, containing above 0·6% silicon is desiliconized in the ladle by means of the oxygen lance. In a typical example, some 18 cwt., or approximately 5% of limestone, ½ cwt. of fluorspar, 5 cwt. of ore or scale, and up to 25% of high-silicon and other pit scrap, melted and desiliconized during blowing, are charged into a 30-ton basic lined ladle, followed by the hot metal charge of about 18 tons. The oxygen is supplied from double twin evaporators through a 2½ in. diam. pipe-line, the gas being introduced into the metal through a ¾ in. mild steel lance. The rate of flow is 300/400 cu.ft./min. at approximately 200 lb./sq.in., the oxygen used being measured by a recording meter and checked, as liquid oxygen, at the evaporator. The average oxygen consumption is approximately 315 cu.ft./ton. In Brymbo practice, the ladle is fitted with a fume hood connected to an exhaust duct, the lance being inserted through a port in the hood. Desiliconizing was found to be more efficient when a slag is formed. In all cases, there is an appreciable increase in temperature and there is a fairly appreciable loss of manganese, but not to below 0·3%. The process can lead also to lower sulphur, e.g. 0·061% to 0·040%; the silicon is readily reduced from 1·1% to 0·3%, and the phosphorus is reduced slightly. (X.10.)

Carbon Dioxide (CO_2) Process. A process for hardening moulds or cores, in which gas is blown through dry clay-free silica sand to precipitate silica in the form of a gel from the sodium silicate binder. (X. 27.)

Chelation. The reaction of a metallic ion with an organic molecule, but only where the latter contains both acidic and basic functional groups and both combine with the metallic ion.

Cincinnati Hydromatic Drawing Process. (See HYDROMATIC DRAWING PROCESS.)

Debitgraphe. A flowmeter which continuously records the rate at which air is blown into the Bessemer converter, expressed in cubic feet per minute at N.T.P. Actuated by a diaphragm inserted in the blast main, the flowmeter includes a device which gives automatic correction for pressure. A fixed temperature correction is made to suit the mean blast temperature. (X. 13.)

Differential Aeration Principle. A principle associated with the name of Dr. U. R. Evans, by whose work it was largely established. In neutral solutions corrosion is essentially a function of oxygen supply, but this is required and used only at the cathodes. The differential aeration principle states that cathodic areas will be encouraged where the concentration of oxygen is greatest, and paradoxically, anodic places (where metal is attacked) will tend to flourish where the oxygen concentration is least. In solutions of alkali salts the effect of oxygen distribution is exerted in virtue of its effect on the distribution of cathodic alkali. Initial starting centres may be innumerable, but the lateral spreading of alkali determines which persist and which are "stifled".

Dohmseal. A refractory coating which is claimed to retard the action of corrosive gases and of temperatures up to 1800° C. It is supplied in the form of a paste, and water is added by the user so that it can be applied to the brickwork of furnaces or kilns in the form of a slurry. This refractory coating can also be used for jointing when mixed with clay grog and produces an effective repair of broken brickwork. (X. 1.)

Dual T.I.G. Welding. A modification of *inert gas arc welding* in which the consumption of a costly inert gas such as argon or helium is reduced to about 25% by making up the balance of the protective atmosphere with carbon dioxide.

Electrophoretic Deposition. This method of producing metallic and composite coatings is based on the movement of charged colloidal particles in a liquid by the application of an electrostatic field. Thus, if two electrodes are immersed in a suspension, and a potential is applied, a deposit of the suspended material collects on one of the electrodes. The process has been developed for the application of nickel, nickel-chromium and nickel-chromium-iron coatings to base metals. Composite coatings of metals and non-metals such as copper-molybdenum disulphide and nickel-silicon carbide may also be deposited. (X. 20.)

Flowturn. A combination of roll forming and spinning which can produce parts difficult or impractical to make by deep drawing. The metal from a blank is squeezed between a roll and a mandrel and is displaced by plastic deformation as the roll advances, extending the length of the blank until the workpiece is formed to the shape determined by the mandrel. Materials that can be worked range from soft aluminium to high tensile stainless steels. (X. 23.)

Fradecal Process. A method of descaling steel, in which a paste, containing a strong electrolyte, is spread on the surface to be descaled. The paste also contains a strong oxidizing agent such as dichromate or permanganate, which removes hydrogen rapidly from the Fe_3O_4 cathode and prevents polarization, thus allowing descaling to proceed. The process is based on the fact that in the presence of an electrolyte the iron, which forms the anode, dissolves, and hydrogen is released under the Fe_3O_4, causing it to be lifted from the iron. (X. 28.)

Herty Viscosimeter. This consists of a split low-carbon steel mould, provided with a conical shaped well into which the molten slag is poured and allowed to flow through a ¼ in. diam. tube, 10 to 12 in. long. The viscosity of the slag is recorded as the distance in inches travelled by the molten slag along this tube before solidification. Whilst it provides a good guide to the composition of acid open hearth slags, it is less accurate with basic slags. The observed distance of flow is not only a factor of the true viscosity of the slag, but is also affected by the melting point of the slag, the superheat and the surface tension, all of which are associated with the composition of the slag; and by the method of sampling and the pouring technique. The distance of flow is also affected by fluorspar additions and the iron oxide of the slag.

Hortonclad Process. A brazing process in which the two metals to be joined are placed in a furnace with a thin foil of brazing alloy between them. As the brazing alloy melts, a vacuum of 29 to 30 in. of mercury is drawn between the plates, which are thus forced together by atmospheric pressure. Thinner alloy layers, new combinations of metals, and better surface finishes are claimed for the process. Forming characteristics and mechanical properties of the composite sheets are reported to be very satisfactory. (X. 19.)

Hydromatic Drawing Process. (*Cincinnati Hydromatic Drawing Process.*) A deep drawing process in which the blank is in direct contact with the fluid. The tool consists of a container of the desired shape of the finished part which is filled with water, with a lid designed so that its sealing gland also serves as blank holder, and recessed to admit high pressure water which presses the blank into the lower container from which the low pressure water is allowed to drain

through a control valve. It is claimed that, owing to the restraining action of the low pressure water, and the consequent absence of punch and die friction and of local folds and bulges, this method permits deeper draws. (X. 16.)

Imatra Process (Solid Lime). In this method desulphurization of killed and semi-killed grades of tonnage steel, made by the electric arc process, is carried out partly in the furnace, under an ordinary oxidizing slag, and partly in the ladle, using a slag consisting of 70% burned lime, 24% fluorspar, and 6% ferro-silicon, the amount of slag used being approximately 1% of the steel weight. The lime and the fluorspar must be less than 4 mm. in size and the ferro-silicon less than 1 mm. The furnaces are tapped below the slag level, the slag itself being held until all the steel is in the ladle. The solid desulphurizing slag is added when about one-fifth of the steel has been tapped, the addition being made either from a tilting carriage or from a ladle feeder suspended from the pouring crane. The slag has melted by the time the ladle is about half-full. From then on, the tapping stream is directed tangentially into the ladle in order to promote efficient mixing. A 28-ton heat is tapped in about 5 mins. The steel temperature, when using desulphurizing slags, should be some 20° C. higher than usual. (X. 9.)

I^2RT Automatic Submerged-Arc Welding Process. An automatic submerged-arc welding process in which the electrode is preheated to its melting point before it enters the arc; thus the arc does not have to supply the heat required to bring the metal to the melting point as in standard submerged-arc processes. It is claimed that with a current of 1000 amp. I^2RT welding can deposit metal at the rate of 100 lb./hr., whereas comparable commercial welding processes deposit only 30 lb./hr. with the same current. (X. 7.)

J.A.M. Coating Process. An accelerated manganese phosphate-coating process. This is said to overcome the usual objections to the use of manganese in that the operational temperature for the process is not significantly higher than that required for zinc phosphates. The accelerators employed have brought the normal treatment time down to 1 to 2 min. It is claimed that this process has superior paint-adhesion properties, and the evenness of the coating texture is less dependent on surface conditions than in the case of zinc phosphate, and it is much more resistant to corrosion arising from humid conditions. (X. 11.)

Maprodent Process. A modified form of the *lost-wax process* in which, instead of rigid metal moulds, deformable moulds are used for the wax models. The moulds are lined with a refractory material and baked; then the wax is injected under centrifugal pressure and in a vacuum. Owing to the deformability of the mould material, complex shapes can be imparted to the wax models, and the moulds are cheap and can be made in a few hours. The pieces can ordinarily be cast to dimensional tolerances of ± 0·1 mm. per 1 cm., but tolerances as small as 0·02 mm. per 1 cm. can be obtained. (X. 12.)

Nondestructive Test for Intergranular Corrosion. An instrument has been developed to indicate the relative intergranular corrosion of austenitic stainless steel tubes by using eddy currents to determine their effective electrical resistivity. The sensing element of the instrument is the coil of an oscillator circuit. When the coil, or probe, is placed upon a sample of tubing, eddy currents are induced in the sample at the expense of energy from the oscillator circuit. The induced eddy currents produce an opposing magnetic field that alters the impedance of the probe. The amplitude of the oscillation is a function of the electrical conductivity of the sample, if all samples are dimensionally alike and the probe-to-sample geometry is uniform. The instrument possesses good stability, and meter readings are unaffected by the electrical shunting of the installed tubing. Differences of 1% in resistivity are detectable. The instrument was designed to test many short sections of tubing located in a congested assembly. (X. 18.)

N.P.L. Ultrasonic Techniques. A notable advance is the use of barium titanate in place of quartz as a piezoelectric material for the generation of medium and high intensities of ultrasonic waves. The application of this material to ultrasonic flaw detection has effected great improvements in resolution and in the avoidance of confused indications when testing on rough surfaces. Barium titanate transducers can take many forms, and even complex shapes can be quite cheaply produced. Workers at the National Physical Laboratory have studied the application of mechanical and electrical damping to transducers to improve discrimination. They have also developed steerable devices to direct the beam at an angle to the surface and to vary that angle. These devices can be operated

electrically to permit the results of testing several beam positions to be displayed simultaneously without moving the probe. Further alteration of the beam angle at the same site can be effected mechanically. (X. 26.)

Nylon-Coated Metal. Adherent coatings of nylon ranging in thickness from 0·002 to 0·030 in. are applied to many types of steel. Applications include the coating of cams, rollers, bushings, guides, gears, etc. It is claimed that the application of these coatings gives the good frictional and anti-wear characteristics of nylon together with the dimensional stability and strength of metals. (X. 25.)

Opacimeter. The instrument depends on the passage of light from a constant source through the Bessemer converter flame on to a photo-electric cell, the cell current being amplified and recorded as a measure of opacity, thus permitting the blower to follow the changes in flame opacity on a recording chart. It is claimed that the use of this instrument overcomes the difficulty presented by the fact that the end point in basic converter practice must be accurate to within a few seconds if the metal is to be sufficiently dephosphorized and yet not over-oxidized. Preceding blows can be used as a guide to the timing of the end point from the start of dephosphorizing and the appearance of the flame can also be helpful, but errors are known to occur when relying thus on the personal judgment of blowers, errors which are inclined to be greater when the temperature of the metal is higher than average. (X. 13.)

Peroxygen Compounds. These comprise hydrogen peroxides, compounds forming hydrogen peroxides in solution, persulphates and peracids. It is claimed that such compounds are actually or potentially useful in forming oxide films on metal surfaces, cleaning impurities from metal surfaces or removing the metal itself, and keeping constituents of certain metal-treating solutions in the proper state of oxidation. For example, a relatively rust-resistant finish can be conferred on ferrous parts by immersing them in a hot alkaline solution, e.g. sodium hydroxide, containing an oxidizing agent (sodium or hydrogen peroxide). A durable black finish for zinc and cadmium is obtained by treatment in a bath containing a soluble copper salt and a chlorate, followed by treatment with a permanganate and a hydrogen peroxide solution. Peroxygen compounds are useful in bright-dip processes, which produce bright metal surfaces with greater stain-resistance than that of untreated parts and which may be beneficial in subsequent coating or forming operations. (X. 15.)

Pertechnetate Ion. The pertechnetate ion TcO_4 is claimed to inhibit corrosion of iron and carbon steels in aerated water at temperatures from 23° to 250° C. The chemical and nuclear properties of technetium show that only radiochemical traces need be precipitated to obtain inhibition. (X. 5.)

Petalite. A lithium aluminium silicate mineral. The mineral as mined is remarkably free from impurities and corresponds very closely with its theoretical formula, $Li_2O.Al_2O_3.8SiO_2$. It is used as a raw material in the manufacture of ceramics and refractories on account of its remarkable resistance to thermal shock.

Philips Roughness Tester. A surface testing instrument which is mains-operated, weighs only 13 lb. and measures 11 in. × 11 in. × 7 in. It is readily portable and can be used anywhere where a power supply of 110 to 245 volt, 40 to 100 c.p.s. is available. The equipment comprises a piezo-electric pickup with a sapphire stylus, a set of reference surfaces, and a selective amplifier giving direct reading on four different scales, 250–50, 60–10, 16–3, and 4–1 micro-inches respectively. The comparison standards are machined to a finish approximating to the middle value in each of the above four ranges and each standard is then individually calibrated by Talysurf measurement. The tester is stated to be sufficiently accurate for all normal production purposes, but nevertheless, can be used in the shop by semi-skilled operators after only brief instruction. (X. 3.)

Piezo-electric Strain Gauge. A gauge having great sensitivity based on the use of a thin wafer of barium titanate in which piezo-electric properties are induced by a polarizing process. Barium titanate is a fired ceramic material that can be shaped before firing, and the electrical axes can be orientated, as desired, by the polarizing process. Compared with other piezo-electric materials, the substance has a very high dielectric constant. (X. 17.)

Raytheon. An ultrasonic machine tool which converts electrical energy into mechanical motion. This motion, present in the tool tip which is doing the cutting, is perpendicular to the work piece and varies between 0 and ± 0·002 in. at a rate of 27,000 times per second. Under these conditions, the tool tip is accelerated at a rate of from 100 to 150 thousand gravities. An

abrasive suspended in some vehicle such as water is made to flow between this vibrating tool and the work piece. (X. 2.)

Reflection Electron Microscopy. A method of examination in which the surface is viewed obliquely, and the protuberances thereon are thus seen in profile. The method is particularly suitable for the examination of surfaces on which the irregularities are small; and ground, lapped, finely-abraded, and polished surfaces can conveniently be studied. (X. 8.)

Rustrem MS. A single-coat rust and corrosion-resistant paint, which can be satisfactorily applied even over damp metal surfaces. This paint combines a heavy bituminous alkyd base with a special penetrating vehicle, and is reputed to penetrate through moisture to the surface metal. It is especially recommended for winter application or use where it is practically impossible to dry a metal surface thoroughly, and it is particularly suitable for use in coastal areas or in tropical climates. The paint can be applied by brush, spray or roller.

Slag Pancake Method. A method of slag control which consists of pouring molten slag into a cast steel mould or receptacle about 4½ in. diam, and about ⅜ in. deep, with slightly tapering walls. The molten slag is poured rapidly into the mould and the pancake removed from the mould as soon as it solidifies, as prolonged contact with the mould causes the underside of the sample to become dull. Careful standardization is essential, especially regarding the pouring technique and the removal of the sample from the mould. Examination of the pancakes obtained in this manner gives considerable information regarding the basicity of the slag, which is judged from the furrows, creases and markings on the surface. A flat or slightly concave surface, characterized by a columnar or acicular fracture with the fibres running perpendicular from the top to the bottom surface is indicative of a low basicity. This type of pancake frequently shows a shrinkage void in the centre.

Ternstedt-Spray Process. An electrostatic painting process. As paint emerges from a spray gun, it is atomized by impinging streams of air, the particles being then given a static charge of electricity by being projected through an ionized field. Subsequently, the charged particles of paint are attracted to the uncharged article to be coated, because of the difference in electrical potential. The ionized field is produced by a device consisting of a high voltage needle electrode, an earth plate and a plastic insulator. This needle electrode is connected to a high voltage power supply. (X. 21.)

Twin-Argon Welding Process. An inert-gas shielded polyphase tungsten arc process developed for the high speed mechanized welding of cable sheathing and metal tube manufacture. (X. 6.)

Ultrasonic Temperature Measurement. This method depends on the determination of the velocity of propagation of sound, which, in a gaseous medium, depends on temperature. A transient sound pulse is generated and detected inside the test chamber; transit time as defined by the interval between corresponding points of the transmitted and detected signal is determined by means of calibrated electronic circuits. Knowledge of the transmission-path length and of the transit time gives the velocity of sound. With the relationship between sound velocity and temperature known, the gas temperature can be reckoned from the propagation time and path length. Components making up the electronic apparatus are the sound generator, receiver, and the time-measuring device. Sound generator and receiver depend on the use of barium titanate crystals with fired-on-electrodes and a natural frequency of about 2 Mc./s. A calibrated Dumont 256-F sweep oscilloscope is used as the time-measuring device. (X. 14.)

Volume Debitgraphe. (See DEBITGRAPHE.)

White Rust. A defect found on the surface of galvanized articles. It consists of zinc carbonate and hydroxide. Actual corrosion may be only very slight and dipping in sodium bichromate solution will inhibit its formation. (X. 4.)

REFERENCES

APPENDICES

APPENDIX I

CONVERSION TABLES (a to n)

APPENDIX I (a)

Equivalent Degrees, Fahrenheit and Centigrade

The middle column gives the value to be converted. If this value is degrees Centigrade, the equivalent degrees Fahrenheit will be found in the right-hand column. If this value is degrees Fahrenheit, the equivalent degrees Centigrade will be found in the left-hand column.

−459·4 to 0

C		F
−273	−459·4	
−268	−450	
−262	−440	
−257	−430	
−251	−420	
−246	−410	
−240	−400	
−234	−390	
−229	−380	
−223	−370	
−218	−360	
−212	−350	
−207	−340	
−201	−330	
−196	−320	
−190	−310	
−184	−300	
−179	−290	
−173	−280	
−169	−273	−459·4
−168	−270	−454
−162	−260	−436
−157	−250	−418
−151	−240	−400
−146	−230	−382
−140	−220	−364
−134	−210	−346
−129	−200	−328
−123	−190	−310
−118	−180	−292
−112	−170	−274
−107	−160	−256
−101	−150	−238
− 96	−140	−220
− 90	−130	−202
− 84	−120	−184
− 79	−110	−166
− 73	−100	−148
− 68	− 90	130
− 62	− 80	−112
− 57	− 70	− 94
− 51	− 60	− 76
− 46	− 50	− 58
− 40	− 40	− 40
− 34	− 30	− 22
− 29	− 20	− 4
− 23	− 10	14
− 17·8	0	32

0 to 100

C		F	C		F
−17·8	0	32	10·0	50	122·0
−17·2	1	33·8	10·6	51	123·8
−16·7	2	35·6	11·1	52	125·6
−16·1	3	37·4	11·7	53	127·4
−15·6	4	39·2	12·2	54	129·2
−15·0	5	41·0	12·8	55	131·0
−14·4	6	42·8	13·3	56	132·8
13·9	7	44·6	13·9	57	134·6
−13·3	8	46·4	14·4	58	136·4
−12·8	9	48·2	15·0	59	138·2
−12·2	10	50·0	15·6	60	140·0
−11·7	11	51·8	16·1	61	141·8
11·1	12	53·6	16·7	62	143·6
−10·6	13	55·4	17·2	63	145·4
−10·0	14	57·2	17·8	64	147·2
9·4	15	59·0	18·3	65	149·0
− 8·9	16	60·8	18·9	66	150·8
8·3	17	62·6	19·4	67	152·6
− 7·8	18	64·4	20·0	68	154·4
− 7·2	19	66·2	20·6	69	156·2
− 6·7	20	68·0	21·1	70	158·0
− 6·1	21	69·8	21·7	71	159·8
− 5·6	22	71·6	22·2	72	161·6
− 5·0	23	73·4	22·8	73	163·4
− 4·4	24	75·2	23·3	74	165·2
− 3·9	25	77·0	23·9	75	167·0
− 3·3	26	78·8	24·4	76	168·8
− 2·8	27	80·6	25·0	77	170·6
− 2·2	28	82·4	25·6	78	172·4
− 1·7	29	84·2	26·1	79	174·2
1·1	30	86·0	26·7	80	176·0
− 0·6	31	87·8	27·2	81	177·8
0·0	32	89·6	27·8	82	179·6
0·6	33	91·4	28·3	83	181·4
1·1	34	93·2	28·9	84	183·2
1·7	35	95·0	29·4	85	185·0
2·2	36	96·8	30·0	86	186·8
2·8	37	98·6	30·6	87	188·6
3·3	38	100·4	31·1	88	190·4
3·9	39	102·2	31·7	89	192·2
4·4	40	104·0	32·2	90	194·0
5·0	41	105·8	32·8	91	195·8
5·6	42	107·6	33·3	92	197·6
6·1	43	109·4	33·9	93	199·4
6·7	44	111·2	34·4	94	201·2
7·2	45	113·0	35·0	95	203·0
7·8	46	114·8	35·6	96	204·8
8·3	47	116·6	36·1	97	206·6
8·9	48	118·4	36·7	98	208·4
9·4	49	120·2	37·2	99	210·2
			37·8	100	212·0

100 to 1000

C		F	C		F
38	100	212	260	500	932
43	110	230	266	510	950
49	120	248	271	520	968
54	130	266	277	530	986
60	140	284	282	540	1004
66	150	302	288	550	1022
71	160	320	293	560	1040
77	170	338	299	570	1058
82	180	356	304	580	1076
88	190	374	310	590	1094
93	200	392	316	600	1112
99	210	410	321	610	1130
100	212	413·6	327	620	1148
104	220	428	332	630	1166
110	230	446	338	640	1184
116	240	464	343	650	1202
121	250	482	349	660	1220
127	260	500	354	670	1238
132	270	518	360	680	1256
138	280	536	366	690	1274
143	290	554	371	700	1292
149	300	572	377	710	1310
154	310	590	382	720	1328
160	320	608	388	730	1346
166	330	626	393	740	1364
171	340	644	399	750	1382
177	350	662	404	760	1400
182	360	680	410	770	1418
188	370	698	416	780	1436
193	380	716	421	790	1454
199	390	734	427	800	1472
204	400	752	432	810	1490
210	410	770	438	820	1508
216	420	788	443	830	1526
221	430	806	449	840	1544
227	440	824	454	850	1562
232	450	842	460	860	1580
238	460	860	466	870	1598
243	470	878	471	880	1616
249	480	896	477	890	1634
254	490	914	482	900	1652
			488	910	1670
			493	920	1688
			499	930	1706
			504	940	1724
			510	950	1742
			516	960	1760
			521	970	1778
			527	980	1796
			532	990	1814
			538	1000	1832

Equivalent Degrees, Fahrenheit and Centigrade—Continued

The middle column gives the value to be converted. If this value is degrees Centigrade, the equivalent degrees Fahrenheit will be found in the right-hand column. If this value is degrees Fahrenheit, the equivalent degrees Centigrade will be found in the left-hand column.

1000 to 2000						2000 to 3000					
C		F	C		F	C		F	C		F
538	1000	1832	816	1500	2732	1093	2000	3632	1371	2500	4532
543	1010	1850	821	1510	2750	1099	2010	3650	1377	2510	4550
549	1020	1868	827	1520	2768	1104	2020	3668	1382	2520	4568
554	1030	1886	832	1530	2786	1110	2030	3686	1388	2530	4586
560	1040	1904	838	1540	2804	1116	2040	3704	1393	2540	4604
566	1050	1922	843	1550	2822	1121	2050	3722	1399	2550	4622
571	1060	1940	849	1560	2840	1127	2060	3740	1404	2560	4640
577	1070	1958	854	1570	2858	1132	2070	3758	1410	2570	4658
582	1080	1976	860	1580	2876	1138	2080	3776	1416	2580	4676
588	1090	1994	866	1590	2894	1143	2090	3794	1421	2590	4694
593	1100	2012	871	1600	2912	1149	2100	3812	1427	2600	4712
599	1110	2030	877	1610	2930	1154	2110	3830	1432	2610	4730
604	1120	2048	882	1620	2948	1160	2120	3848	1438	2620	4748
610	1130	2066	888	1630	2966	1166	2130	3866	1443	2630	4766
616	1140	2084	893	1640	2984	1171	2140	3884	1449	2640	4784
621	1150	2102	899	1650	3002	1177	2150	3902	1454	2650	4802
627	1160	2120	904	1660	3020	1182	2160	3920	1460	2660	4820
632	1170	2138	910	1670	3038	1188	2170	3938	1466	2670	4838
638	1180	2156	916	1680	3056	1193	2180	3956	1471	2680	4856
643	1190	2174	921	1690	3074	1199	2190	3974	1477	2690	4874
649	1200	2192	927	1700	3092	1204	2200	3992	1482	2700	4892
654	1210	2210	932	1710	3110	1210	2210	4010	1488	2710	4910
660	1220	2228	938	1720	3128	1216	2220	4028	1493	2720	4928
666	1230	2246	943	1730	3146	1221	2230	4046	1499	2730	4946
671	1240	2264	949	1740	3164	1227	2240	4064	1504	2740	4964
677	1250	2282	954	1750	3182	1232	2250	4082	1510	2750	4982
682	1260	2300	960	1760	3200	1238	2260	4100	1516	2760	5000
688	1270	2318	966	1770	3218	1243	2270	4118	1521	2770	5018
693	1280	2336	971	1780	3236	1249	2280	4136	1527	2780	5036
699	1290	2354	977	1790	3254	1254	2290	4154	1532	2790	5054
704	1300	2372	982	1800	3272	1260	2300	4172	1538	2800	5072
710	1310	2390	988	1810	3290	1266	2310	4190	1543	2810	5090
716	1320	2408	993	1820	3308	1271	2320	4208	1549	2820	5108
721	1330	2426	999	1830	3326	1277	2330	4226	1554	2830	5126
727	1340	2444	1004	1840	3344	1282	2340	4244	1560	2840	5144
732	1350	2462	1010	1850	3362	1288	2350	4262	1566	2850	5162
738	1360	2480	1016	1860	3380	1293	2360	4280	1571	2860	5180
743	1370	2498	1021	1870	3398	1299	2370	4298	1577	2870	5198
749	1380	2516	1027	1880	3416	1304	2380	4316	1582	2880	5216
754	1390	2534	1032	1890	3434	1310	2390	4334	1588	2890	5234
760	1400	2552	1038	1900	3452	1316	2400	4352	1593	2900	5252
766	1410	2570	1043	1910	3470	1321	2410	4370	1599	2910	5270
771	1420	2588	1049	1920	3488	1327	2420	4388	1604	2920	5288
777	1430	2606	1054	1930	3506	1332	2430	4406	1610	2930	5306
782	1440	2624	1060	1940	3524	1338	2440	4424	1616	2940	5324
788	1450	2642	1066	1950	3542	1343	2450	4442	1621	2950	5342
793	1460	2660	1071	1960	3560	1349	2460	4460	1627	2960	5360
799	1470	2678	1077	1970	3578	1354	2470	4478	1632	2970	5378
804	1480	2696	1082	1980	3596	1360	2480	4496	1638	2980	5396
810	1490	2714	1088	1990	3614	1366	2490	4514	1643	2990	5414
			1093	2000	3632				1649	3000	5432

Tensile Strength and Corresponding Hardness of Steel

Tons per Sq. in.	Lbs. per Sq. in.	Kilos. per Sq. m/m	Approx. Hardness		Tons per Sq. in.	Lbs. per Sq. in.	Kilos. per Sq. m/m	Approx. Hardness	
			Brinell No.	Dia. of Impression				Brinell No.	Dia. of Impression
10	22,400	15·75	—	—	52	116,480	81·90	241	3·90
11	24,640	17·32	—	—	54	120,960	85·05	248	3·85
12	26,880	18·90	—	—	56	125,440	88·20	255	3·80
13	29,120	20·47	—	—	58	129,920	91·35	262	3·75
14	31,360	22·05	—	—	60	134,400	94·50	277	3·70
15	33,600	23·62	—	—	62	138,880	97·65	285	3·60
16	35,840	25·20	69	—	64	143,360	100·80	293	3·55
17	38,080	26·77	74	—	66	147,840	103·95	302	3·50
18	40,320	28·35	79	—	68	152,320	107·10	311	3·45
19	42,560	29·92	82	—	70	156,800	110·25	321	3·40
20	44,800	31·50	87	—	72	161,280	113·40	331	3·35
21	47,040	33·07	92	—	74	165,760	116·55	341	3·30
22	49,280	34·65	97	5·95	76	170,240	119·70	352	3·25
23	51,520	36·22	101	5·85	78	174,720	122·85		
24	53,760	37·80	105	5·75	80	179,200	126·00	363	3·20
25	56,000	39·37	109	5·65	82	183,680	129·15	375	3·15
26	58,240	40·95	114	5·55	84	188,160	132·30	388	3·10
27	60,480	42·52	118	5·45	86	192,640	135·45		
28	62,720	44·10	121	5·40	88	197,120	138·60	401	3·05
29	64,960	45·67	126	5·30	90	201,600	141·75		
30	67,200	47·25	131	5·20	92	206,080	144·90	415	3·00
31	69,440	48·82	137	5·10	94	210,560	148·05	429	2·95
32	71,680	50·40	143	5·00	96	215,040	151·20		
33	73,920	51·97	149	4·90	98	219,520	154·35	444	2·90
34	76,160	53·55	156	4·80	100	224,000	157·50		
35	78,400	55·12	163	4·70	102	228,480	160·65		
36	80,640	56·70	167	4·65	104	232,960	163·80	477	2·80
37	82,880	58·27	170	4·60	106	237,440	166·95		
38	85,120	59·85	174	4·55	108	241,920	170·10	495	2·75
39	87,360	61·42	179	4·50	110	246,400	173·25		
40	89,600	63·00	183	4·45	112	250,880	176·40	514	2 70
41	91,840	64·57	187	4·40	114	255,360	179·55		
42	94,080	66·15	192	4·35	116	259,840	182·70	534	2·65
43	96,320	67·72	197	4·30	118	264,320	185·85		
44	98,560	69·30	201	4·25	120	268,800	189·00		
45	100,800	70·87	207	4·20	122	273,280	192·15	555	2 60
46	103,040	72·45	212	4·15	124	277,760	195·30		
47	105,280	74·02	217	4·10	126	282,240	198·45	578	2 55
48	107,520	75·60			128	286,720	201·60		
49	109,760	77·17	223	4·05	130	291,200	204·85		
50	112,000	78·75	229	4·00	132	295,680	208·00	601	2·50

APPENDIX I (c)

BRINELL HARDNESS

and Approximate Equivalent Tensile Strength; Diamond, Rockwell and Scleroscope Hardness.

Hardometer Scale Reading, 30 kg. (135° Diamond Indenter).	Diamond Hardness Number	Brinell Impression Diam. in mm.	Brinell Hardness Number	Approx. Tensile Strength, Tons/sq. in.	Rockwell Hardness Number	Shore Scleroscope Number*
2·35	1007	—	—	—	C68	101
2·40	966	—	—	—	67	98
2·45	927	—	—	—	66	96
2·50	890	—	—	—	65	94
2·55	856	—	—	—	64	92
2·60	823	—	—	—	63	90
2·65	792	—	—	—	62	88
2·725	749	—	—	—	61	85
2·75	736	2·45	627	—	60½	84
2·825	698	2·50	601	132	59	81
2·90	661	2·55	578	127	C57	78
2·975	628	2·60	555	122	55	75
3·05	598	2·65	534	117	53½	72
3·125	570	2·70	514	112	52	70
3·20	543	2·75	495	108	50½	67
3·275	519	2·80	477	104	49	65
3 35	496	2·85	461	101	47½	63
3·425	474	2·90	444	98	46	61
3·50	454	2·95	429	95	45	59
3·55	441	3·00	415	92	43½	57
3·625	423	3·05	401	88	C42	55
3·70	406	3·10	388	85	41	54
3·775	390	3·15	375	82	40	52
3·85	375	3·20	363	80	38	50
3·90	366	3·25	352	77	37	49
3·975	352	3·30	341	74	36	47
4·05	339	3·35	331	72	35	46
4·10	331	3·40	321	70	34	45
4·20	315	3·45	311	68	33	44
4·25	308	3·50	302	66	32	43
4·325	298	3·55	293	64	C31	42
4·40	287	3·60	285	62	30	41
4·45	281	3·65	277	60	29	40
4·525	272	3·70	269	59	28	39
4·575	265	3·75	262	58	27	38
4·65	257	3·80	255	56	26	37
4·725	250	3·85	248	54	24	36
4·80	242	3·90	241	52	23	35
4·85	237	3·95	235	51	22	34
4·925	230	4·00	229	50	B99	34

Hardometer Scale Reading, 30 kg. (136° Diamond Indenter).	Diamond Hardness Number.	Brinell Impression Diam. in mm.	Brinell Hardness Number.	Approx. Tensile Strength, Tons/sq. in.	Rockwell Hardness Number	Shore Scleroscope Number.*
5·00	223	4·05	223	49	B98	33
5·05	218	4·10	217	47	97	32
5·10	214	4·15	212	46	96	31
5·20	206	4·20	207	45	95	31
5·25	202	4·25	201	44	94	30
5·30	198	4·30	197	43	93	29
5·40	191	4·35	192	42	92	29
5·45	187	4·40	187	41	91	28
5·50	184	4·45	183	40	90	28
5·60	177	4·50	179	39	89	27
5·65	174	4·55	174	38	B88	27
5·70	171	4·60	170	37	87	26
5·75	168	4·65	167	36	86	26
5·85	163	4·70	163	35	85	25
5·90	160	4·75	159	34·5	84	25
5·95	157	4·80	156	34	83	24
6·05	152	4·85	152	33·5	82	24
6·10	150	4·90	149	33	81	23
6·20	145	4·95	146	32·5	80	23
6·25	142	5·00	143	32	78	—
6·30	140	5·05	140	31·5	B77	—
6·40	136	5·10	137	31	76	—
6·45	134	5·15	134	30·5	75	—
6·50	132	5·20	131	30	74	—
—	—	5·25	128	29·5	72	—
—	—	5·30	126	29	71	—
—	—	5·35	123	28·5	70	—
—	—	5·40	121	28	69	—
—	—	5·45	118	27	67	—
—	—	5·50	116	26·5	66	—
—	—	5·55	114	26	B65	—
—	—	5·60	111	25·5	63	—
—	—	5·65	109	25	62	—
—	—	5·70	107	24·5	61	—
—	—	5·75	105	24	59	—

* This conversion to Scleroscope Hardness applies to small pieces (about 1 in. diameter). For larger pieces the corresponding Shore Numbers are higher, e.g., for 8 in. diameter rolls the Shore values are 5 to 8 points higher than given in the table.

POUNDS TO TONS OR POUNDS PER SQUARE INCH TO TONS PER SQUARE INCH

1000 lb.	0	100	200	300	400	500	600	700	800	900
	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons
—	—	0·04464	0·08929	0·13393	0·17857	0·22321	0·26786	0·31250	0·35714	0·40179
1	0·44643	0·49107	0·53571	0·58036	0·62500	0·66964	0·71429	0·75893	0·80357	0·84821
2	0·89286	0·93750	0·98214	1·02679	1·07143	1·11607	1·16071	1·20536	1·25000	1·29464
3	1·33929	1·38393	1·42857	1·47321	1·51786	1·56250	1·60714	1·65179	1·69643	1·74107
4	1·78571	1·83036	1·87500	1·91964	1·96429	2·00893	2·05357	2·09821	2·14286	2·18750
5	2·23214	2·27679	2·32143	2·36607	2·41071	2·45536	2·50000	2·54464	2·58929	2·63393
6	2·67857	2·72321	2·76786	2·81250	2·85714	2·90179	2·94643	2·99107	3·03571	3·08036
7	3·12500	3·16964	3·21429	3·25893	3·30357	3·34821	3·39286	3·43750	3·48214	3·52679
8	3·57143	3·61607	3·66071	3·70536	3·75000	3·79464	3·83929	3·88393	3·92857	3·97321
9	4·01786	4·06250	4·10714	4·15179	4·19643	4·24107	4·28571	4·33036	4·37500	4·41964
10	4·46429	4·50893	4·55357	4·59821	4·64286	4·68750	4·73214	4·77679	4·82143	4·86607
11	4·91071	4·95536	5·0000	5·0446	5·0893	5·1339	5·1786	5·2232	5·2679	5·3125
12	5·3571	5·4018	5·4464	5·4911	5·5357	5·5804	5·6250	5·6696	5·7143	5·7589
13	5·8036	5·8482	5·8929	5·9375	5·9821	6·0268	6·0714	6·1161	6·1607	6·2054
14	6·2500	6·2946	6·3393	6·3839	6·4286	6·4732	6·5179	6·5625	6·6071	6·6518
15	6·6964	6·7411	6·7857	6·8304	6·8750	6·9196	6·9643	7·0089	7·0536	7·0982
16	7·1429	7·1875	7·2321	7·2768	7·3214	7·3661	7·4107	7·4554	7·5000	7·5446
17	7·5893	7·6339	7·6786	7·7232	7·7679	7·8125	7·8571	7·9018	7·9464	7·9911
18	8·0357	8·0804	8·1250	8·1696	8·2143	8·2589	8·3036	8·3482	8·3929	8·4375
19	8·4821	8·5268	8·5714	8·6161	8·6607	8·7054	8·7500	8·7946	8·8393	8·8839
20	8·9286	8·9732	9·0179	9·0625	9·1071	9·1518	9·1964	9·2411	9·2857	9·3304
21	9·3750	9·4196	9·4643	9·5089	9·5536	9·5982	9·6429	9·6875	9·7321	9·7768
22	9·8214	9·8661	9·9107	9·9554	10·0000	10·0446	10·0893	10·1339	10·1786	10·2232
23	10·2679	10·3125	10·3571	10·4018	10·4464	10·4911	10·5375	10·5804	10·6250	10·6696
24	10·7143	10·7589	10·8036	10·8482	10·8929	10·9375	10·9821	11·0268	11·0714	11·1161
25	11·1607	11·2054	11·2500	11·2946	11·3393	11·3839	11·4286	11·4732	11·5179	11·5625
26	11·6071	11·6518	11·6964	11·7411	11·7857	11·8304	11·8750	11·9196	11·9643	12·0089
27	12·0536	12·0982	12·1429	12·1875	12·2321	12·2768	12·3214	12·3661	12·4107	12·4554
28	12·5000	12·5446	12·5893	12·6339	12·6786	12·7232	12·7679	12·8125	12·8571	12·9018
29	12·9464	12·9911	13·0357	13·0804	13·1250	13·1696	13·2143	13·2589	13·3036	13·3482
30	13·3929	13·4375	13·4821	13·5268	13·5714	13·6161	13·6607	13·7054	13·7500	13·7946
31	13·8393	13·8839	13·9286	13·9732	14·0179	14·0625	14·1071	14·1518	14·1964	14·2411
32	14·2857	14·3304	14·3750	14·4196	14·4643	14·5089	14·5536	14·5982	14·6429	14·6875
33	14·7321	14·7769	14·8214	14·8661	14·9107	14·9554	15·0000	15·0446	15·0893	15·1339
34	15·1786	15·2232	15·2679	15·3125	15·3571	15·4018	15·4464	15·4911	15·5357	15·5804
35	15·6250	15·6696	15·7143	15·7589	15·8036	15·8482	15·8929	15·9375	15·9821	16·0268
36	16·0714	16·1161	16·1607	16·2054	16·2500	16·2946	16·3393	16·3839	16·4286	16·4732
37	16·5179	16·5625	16·6071	16·6518	16·6964	16·7411	16·7857	16·8304	16·8750	16·9196
38	16·9643	17·0089	17·0536	17·0982	17·1429	17·1875	17·2321	17·2768	17·3214	17·3661
39	17·4107	17·4554	17·5000	17·5446	17·5893	17·6339	17·6786	17·7232	17·7679	17·8125
40	17·8571	17·9018	17·9464	17·9911	18·0357	18·0804	18·1250	18·1696	18·2143	18·2589
41	18·3036	18·3482	18·3929	18·4375	18·4821	18·5268	18·5714	18·6161	18·6607	18·7054
42	18·7500	18·7946	18·8393	18·8839	18·9286	18·9732	18·0179	19·0625	19·1071	19·1518
43	19·1964	19·2411	19·2857	19·3304	19·3750	19·4196	19·4643	19·5089	19·5536	19·5982
44	19·6429	19·6875	19·7321	19·7768	19·8214	19·8661	19·9107	19·9554	20·0000	20·0446
45	20·0893	20·1339	20·1786	20·2232	20·2679	20·3125	20·3571	20·4018	20·4464	20·4911
46	20·5357	20·5804	20·6250	20·6696	20·7143	20·7589	20·8036	20·8482	20·8929	20·9375
47	20·9821	21·0268	21·0714	21·1161	21·1607	21·2054	21·2500	21·2946	21·3393	21·3839
48	21·4286	21·4732	21·5179	21·5625	21·6071	21·6518	21·6964	21·7411	21·7857	21·8304
49	21·8750	21·9196	21·9643	22·0089	22·0536	22·0982	22·1429	22·1875	22·2321	22·2768

APPENDIX I (e)

TONS TO POUNDS OR TONS PER SQUARE INCH TO POUNDS PER SQUARE INCH

Tons	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
—	—	224	448	672	896	1120	1344	1568	1792	2016
1	2240	2464	2688	2912	3136	3360	3584	3808	4032	4256
2	4480	4704	4928	5152	5376	5600	5824	6048	6272	6496
3	6720	6944	7168	7392	7616	7840	8064	8288	8512	8736
4	8960	9184	9408	9632	9856	10080	10304	10528	10752	10976
5	11200	11424	11648	11872	12096	12320	12544	12768	12992	13216
6	13440	13664	13888	14112	14336	14560	14784	15008	15232	15456
7	15680	15904	16128	16352	16576	16800	17024	17248	17472	17696
8	17920	18144	18368	18592	18816	19040	19264	19488	19712	19936
9	20160	20384	20608	20832	21056	21280	21504	21728	21952	22176
10	22400	22624	22848	23072	23296	23520	23744	23968	24192	24416
11	24640	24864	25088	25312	25536	25760	25984	26208	26432	26656
12	26880	27104	27328	27552	27776	28000	28224	28448	28672	28896
13	29120	29344	29568	29792	30016	30240	30464	30688	30912	31136
14	31360	31584	31808	32032	32256	32480	32704	32928	33152	33376
15	33600	33824	34048	34272	34496	34720	34944	35168	35392	35616
16	35840	36064	36288	36512	36736	36960	37184	37408	37632	37856
17	38080	38304	38528	38752	38976	39200	39424	39648	39872	40096
18	40320	40544	40768	40992	41216	41440	41664	41888	42112	42336
19	42560	42784	43008	43232	43456	43680	43904	44128	44352	44576
20	44800	45024	45248	45472	45696	45920	46144	46368	46592	46816
21	47040	47264	47488	47712	47936	48160	48384	48608	48832	49056
22	49280	49504	49728	49952	50176	50400	50624	50848	51072	51296
23	51520	51744	51968	52192	52416	52640	52864	53088	53312	53536
24	53760	53984	54208	54432	54656	54880	55104	55328	55552	55776
25	56000	56224	56448	56672	56896	57120	57344	57568	57792	58016
26	58240	58464	58688	58912	59136	59360	59584	59808	60032	60256
27	60480	60704	60928	61152	61376	61600	61824	62048	62272	62496
28	62720	62944	63168	63392	63616	63840	64064	64288	64512	64736
29	64960	65184	65408	65632	65856	66080	66304	66528	66752	66976
30	67200	67424	67648	67872	68096	68320	68544	68768	68992	69216
31	69440	69664	69888	70112	70336	70560	70784	71008	71232	71456
32	71680	71904	72128	72352	72576	72800	73024	73248	73472	73696
33	73920	74144	74368	74592	74816	75040	75264	75488	75712	75936
34	76160	76384	76608	76832	77056	77280	77504	77728	77952	78176
35	78400	78624	78848	79072	79296	79520	79744	79968	80192	80416
36	80640	80864	81088	81312	81536	81760	81984	82208	82432	82656
37	82880	83104	83328	83552	83776	84000	84224	84448	84672	84896
38	85120	85344	85568	85792	86016	86240	86464	86688	86912	87136
39	87360	87584	87808	88032	88256	88480	88704	88928	89152	89376
40	89600	89824	90048	90272	90496	90720	90944	91168	91392	91616
41	91840	92064	92288	92512	92736	92960	93184	93408	93632	93856
42	94080	94304	94528	94752	94976	95200	95424	95648	95872	96096
43	96320	96544	96768	96992	97216	97440	97664	97888	98112	98336
44	98560	98784	99008	99232	99456	99680	99904	100128	100352	100576
45	100800	101024	101248	101472	101696	101920	102144	102368	102592	102816
46	103040	103264	103488	103712	103936	104160	104384	104608	104832	105056
47	105280	105504	105728	105952	106176	106400	106624	106848	107072	107296
48	107520	107744	107968	108192	108416	108640	108864	109088	109312	109536
49	109760	109984	110208	110432	110656	110880	111104	111328	111552	111776

KILOGRAMS PER SQUARE MILLIMETRE TO TONS PER SQUARE INCH

Kg./mm.²	0	0·1	0·2	0·3	0·4	0 5	0·6	0·7	0·8	0·9
	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.	tons/ sq. in.
—	—	0·06350	0·12699	0·19049	0·25399	0·31749	0·38098	0·44448	0·50798	0·57147
1	0·63497	0·69847	0·76196	0·82546	0·88896	0·95246	1·01595	1·07945	1·14295	1·20644
2	1·26994	1·33344	1·39694	1·46043	1·52393	1·58743	1·65092	1 71442	1·77792	1·84141
3	1·90491	1·96841	2·03191	2·09540	2·15890	2·22240	2·28589	2·34939	2·41289	2·47639
4	2·53988	2·60338	2·66688	2·73037	2·79387	2·85737	2·92086	2·98436	3·04786	3·11136
5	3·17485	3·23835	3·30185	3·36534	3·42884	3·49234	3·55584	3·61933	3·68283	3·74633
6	3·80982	3·87332	3·93682	4·00031	4·06381	4·12731	4·19081	4·25430	4·31780	4·38130
7	4·44479	4·50829	4·57179	4·63529	4·69878	4·76228	4·82578	4·88927	4·95277	5·0163
8	5·0798	5·1433	5·2068	5 2703	5·3338	5·3973	5·4607	5·5242	5·5877	5·6512
9	5·7147	5·7782	5·8417	5·9052	5·9687	6·0322	6·0957	6·1592	6·2227	6·2862
10	6·3497	6·4132	6·4767	6·5402	6·6037	6·6672	6·7307	6·7942	6·8577	6·9212
11	6·9847	7·0482	7·1117	7·1752	7·2387	7·3022	7 3657	7·4292	7·4927	7·5562
12	7 6196	7·6831	7·7466	7·8101	7·8736	7·9371	8·0006	8·0641	8·1276	8·1911
13	8·2546	8·3181	8·3816	8·4451	8·5086	8·5721	8·6356	8·6991	8·7626	8·8261
14	8·8896	8·9531	9·0166	9·0801	9·1436	9·2071	9·2706	9·3341	9·3976	9·4611
15	9·5246	9·5881	9·6516	9·7151	9·7785	9·8420	9·9055	9·9690	10·0325	10·0960
16	10·1595	10·2230	10·2865	10·3500	10·4135	10·4770	10·5405	10·6040	10·6675	10·7310
17	10·7945	10·8580	10·9215	10·9850	11·0485	11·1120	11·1755	11·2390	11·3025	11·3660
18	11·4295	11·4930	11·5565	11·6200	11·6835	11·7470	11·8105	11·8740	11·9374	12·0009
19	12·0644	12·1279	12·1914	12·2549	12·3184	12 3819	12·4454	12·5089	12·5724	12·6359
20	12·6994	12·7629	12·8264	12·8899	12·9534	13·0169	13·0804	13·1439	13·2074	13·2709
21	13·3344	13·3979	13·4614	13·5249	13·5884	13·6519	13·7154	13·7789	13·8424	13·9059
22	13·9694	14·0329	14·0963	14·1598	14·2233	14·2868	14·3503	14·4138	14·4773	14·5408
23	14·6043	14·6678	14·7313	14·7948	14·8583	14·9218	14·9853	15·0488	15·1123	15·1758
24	15·2393	15·3028	15·3663	15·4298	15·4933	15·5568	15·6203	15·6838	15·7473	15·8108
25	15·8743	15·9378	16·0013	16·0648	16·1283	16·1918	16·2552	16 3187	16·3822	16·4457
26	16·5092	16·5727	16·6362	16·6997	16·7632	16·8267	16·8902	16·9537	17·0172	17·0807
27	17·1442	17·2077	17·2712	17 3347	17·3982	17·4617	17·5252	17·5887	17·6522	17 7157
28	17 7792	17·8427	17·9062	17·9697	18·0332	18·0967	18·1602	18·2237	18·2872	18·3507
29	18 4141	18·4776	18·5411	18·6046	18·6681	18·7316	18·7951	18·8586	18·9221	18·9856
30	19·0491	19·1126	19·1761	19·2396	19·3031	19·3666	19·4301	19·4936	19·5571	19·6206
31	19·6841	19·7476	19·8111	19·8746	19·9381	20·0016	20·0651	20·1286	20·1921	30·2556
32	20·3191	20·3826	20·4461	20·5096	20·5730	20·6365	20 7000	20·7635	20·8270	20·8905
33	20·9540	21·0175	21·0810	21 1445	21 2080	21 2715	21 3350	21·3985	21·4620	21·5255
34	21·5890	21·6525	21 7160	21·7795	21·8430	21·9065	21·9700	22·0335	22·0970	22·1605
35	22·2240	22·2875	22 3510	22·4145	22 4780	22·5415	22·6050	22·6685	22·7319	22 7954
36	22 8589	22·9224	22·9859	23·0494	23·1129	23·1764	23·2399	23·3034	23·3669	23·4304
37	23 4939	23·5574	23·6209	23·6844	23 7479	23·8114	23·8749	23·9384	24 0019	24·0654
38	24 1289	24·1924	24·2559	24·3194	24·3829	24·4464	24·5099	24·5734	24·6369	24·7004
39	24·7639	24·8274	24·8908	24·9543	25·0178	25·0813	25·1448	25 2083	25·2718	25·3353
40	25·3988	25·4623	25·5258	25·5893	25·6528	25·7163	25·7798	25·8433	25·9068	25·9703
41	26·0338	26·0973	26 1608	26·2243	26·2878	26 3513	26·4148	26·4783	26·5418	26·6053
42	26 6688	26·7323	26·7958	26·8593	26·9228	26·9863	27·0497	27 1132	27 1767	27·2402
43	27 3037	27 3672	27 4307	27·4942	27·5577	27·6212	27·6847	27 7482	27·8117	27·8752
44	27 9387	28·0022	28·0657	28 1292	28·1927	28·2562	28 3197	28·3832	28·4467	28·5102
45	28 5737	28·6372	28·7007	28·7642	28·8277	28·8912	28·9547	29·0182	29·0817	29·1452
46	29 2086	29·2721	29·3356	29·3991	29·4626	29·5261	29·5896	29·6531	29·7166	29·7801
47	29·8436	29 9071	29·9706	30 0341	30·0976	30·1611	30·2246	30·2881	30 3516	30·4151
48	30·4786	30 5421	30·6056	30·6691	30·7326	30·7961	30·8596	30·9231	30·9866	31·0501
49	31 1136	31·1771	31·2406	31 3041	31 3675	31·4310	31·4945	31·5580	31·6215	31·6850

TONS PER SQUARE INCH TO KILOGRAMS PER SQUARE MILLIMETRE

Tons/ sq. in.	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²	kg./ mm.²
—	—	0·15749	0·31498	0·47246	0·62995	0·78744	0·94493	1·10241	1·25990	1·41739
1	1·57488	1·73236	1·88985	2·04734	2·20483	2·36231	2·51980	2·67729	2·83478	2·99226
2	3·14975	3·30724	3·46473	3·62222	3·77970	3·93719	4·09468	4·25217	4·40965	4·56714
3	4·72463	4·88212	5·0396	5·1971	5·3546	5·5121	5·6696	5·8270	5·9845	6·1420
4	6·2995	6·4570	6·6145	6·7720	6·9295	7·0869	7·2444	7·4019	7·5594	7·7169
5	7·8744	8·0319	8·1894	8·3468	8·5043	8·6618	8·8193	8·9763	9·1343	9·2918
6	9·4493	9·6067	9·7642	9·9217	10·0792	10·2367	10·3942	10·5517	10·7092	10·8666
7	11·0241	11·1816	11·3391	11·4966	11·6541	11·8116	11·9691	12·1265	12·2840	12·4415
8	12·5990	12·7565	12·9140	13·0715	13·2290	13·3864	13·5439	13·7014	13·8589	14·0164
9	14·1739	14·3314	14·4889	14·6463	14·8038	14·9613	15·1188	15·2763	15·4338	15·5913
10	15·7488	15·9062	16·0637	16·2212	16·3787	16·5362	16·6937	16·8512	17·0087	17·1661
11	17·3236	17·4811	17·6386	17·7961	17·9536	18·1111	18·2686	18·4261	18·5835	18·7410
12	18·8985	19·0560	19·2135	19·3710	19·5285	19·6860	19·8434	20·0009	20·1584	20·3159
13	20·4734	20·6309	20·7884	20·9459	21·1033	21·2608	21·4183	21·5758	21·7333	21·8908
14	22·0483	22·2058	22·3632	22·5207	22·6782	22·8357	22·9932	23·1507	23·3082	23·4657
15	23·6231	23·7806	23·9381	24·0956	24·2531	24·4106	24·5681	24·7256	24·8830	25·0405
16	25·1980	25·3555	25·5130	25·6705	25·8280	25·9855	26·1429	26·3004	26·4579	26·6154
17	26·7729	26·9304	27·0879	27·2454	27·4028	27·5603	27·7178	27·8753	28·0328	28·1903
18	28·3478	28·5053	28·6627	28·8202	28·9777	29·1352	29·2927	29·4502	29·6077	29·7652
19	29·9226	30·0801	30·2376	30·3951	30·5526	30·7101	30·8676	31·0251	31·1825	31·3400
20	31·4975	31·6550	31·8125	31·9700	32·1275	32·2850	32·4424	32·5999	32·7574	32·9149
21	33·0724	33·2299	33·3874	33·5449	33·7023	33·8598	34·0173	34·1748	34·3323	34·4898
22	34·6473	34·8048	34·9622	35·1197	35·2772	35·4347	35·5922	35·7497	35·9072	36·0647
23	36·2222	36·3796	36·5371	36·6946	36·8521	37·0096	37·1671	37·3246	37·4821	37·6395
24	37·7970	37·9545	38·1120	38·2695	38·4270	38·5845	38·7420	38·8994	39·0569	39·2144
25	39·3719	39·5294	39·6869	39·8444	40·0019	40·1593	40·3168	40·4743	40·6318	40·7893
26	40·9468	41·1043	41·2618	41·4192	41·5767	41·7342	41·8917	42·0492	42·2067	42·3642
27	42·5217	42·6791	42·8366	42·9941	43·1516	43·3091	43·4666	43·6241	43·7816	43·9390
28	44·0965	44·2540	44·4115	44·5690	44·7265	44·8840	45·0415	45·1989	45·3564	45·5139
29	45·6714	45·8289	45·9864	46·1439	46·3014	46·4588	46·6163	46·7738	46·9313	47·0888
30	47·2463	47·4038	47·5613	47·7187	47·8762	48·0337	48·1912	48·3487	48·5062	48·6637
31	48·8212	48·9786	49·1361	49·2936	49·4511	49·6086	49·7661	49·9236	50·081	50·239
32	50·396	50·554	50·711	50·868	51·026	51·183	51·341	51·498	51·656	51·813
33	51·971	52·128	52·286	52·443	52·601	52·758	52·916	53·073	53·231	53·388
34	53·546	53·703	53·861	54·018	54·176	54·333	54·491	54·648	54·806	54·963
35	55·121	55·278	55·436	55·593	55·751	55·908	56·066	56·223	56·381	56·538
36	56·696	56·853	57·011	57·168	57·325	57·483	57·640	57·798	57·955	58·113
37	58·270	58·428	58·585	58·743	58·900	59·058	59·215	59·373	59·530	59·688
38	59·845	60·003	60·160	60·318	60·475	60·633	60·790	60·948	61·105	61·263
39	61·420	61·578	61·735	61·893	62·050	62·208	62·365	62·523	62·680	62·838
40	62·995	63·153	63·310	63·468	63·625	63·782	63·940	64·097	64·255	64·412
41	64 570	64·727	64·885	65·042	65·200	65·357	65·515	65 672	65·830	65·987
42	66·145	66·302	66·460	66·617	66·775	66·932	67·090	67·247	67·405	67·562
43	67·720	67·877	68·035	68·192	68·350	68·507	68·665	68·822	68·980	69·137
44	69·295	69·452	69·610	69·767	69·924	70·082	70·239	70·397	70·554	70·712
45	70·869	71·027	71·184	71·342	71·499	71 657	71·814	71·972	72·129	72·287
46	72·444	72·602	72·759	72·917	73·074	73·232	73·389	73·547	73·704	73·862
47	74·019	74·177	74·334	74·492	74·649	74·807	74·964	75·122	75·279	75·437
48	75·594	75·752	75·909	76·067	76·224	76·381	76·539	76·696	76·854	77·011
49	77·169	77·326	77·484	77·641	77 799	77·956	78·114	78·271	78·429	78·586

APPENDIX I (h)

KILOGRAMS PER SQUARE MILLIMETRE TO THOUSANDS OF POUNDS PER SQUARE INCH

Based on 1 kg./mm.² = 1422·33 lb./sq. in.

kg./mm.²	0	0·1	0·2	0·3	0·4	0·5	0 6	0 7	0·8	0·9
	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.	1000 lb./ sq. in.
—	—	0·14223	0·28447	0·42670	0·56893	0·71117	0·85340	0·99563	1·13787	1·28010
1	1·42233	1·56457	1·70680	1·84903	1·99127	2·13350	2·27573	2·41797	2·56020	2 70243
2	2·84467	2 98690	3·12914	3·27137	3·41360	3 55584	3·69807	3·84030	3·98254	4·12477
3	4·26700	4·40924	4·55147	4·69370	4·83594	4·97817	5·1204	5·2626	5·4049	5·5471
4	5·6893	5·8316	5·9738	6·1160	6·2583	6·4005	6·5427	6·6850	6·8272	6·9694
5	7·1117	7·2539	7·3961	7·5384	7·6806	7·8228	7·9651	8·1073	8·2495	8·3918
6	8·5340	8·6762	8·8185	8·9607	9·1029	9·2452	9·3874	9·5296	9·6719	9·8141
7	9·9563	10·0986	10·2408	10·3830	10·5253	10 6675	10·8097	10·9520	11·0942	11·2364
8	11·3787	11·5209	11·6631	11·8054	11·9476	12·0898	12·2321	12·3743	12·5165	12·6588
9	12·8010	12·9432	13·0855	13·2277	13·3699	13·5122	13·6544	13·7966	13·9389	14·0811
10	14·2233									

APPENDIX I (i)

THOUSANDS OF POUNDS PER SQUARE INCH TO KILOGRAMS PER SQUARE MILLIMETRE

1000 lb./ sq. in.	0	100	200	300	400	500	600	700	800	900
	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²	kg./mm.²
—	—	0·7031	1·4061	2·1092	2·8123	3·5153	4·2184	4·9215	5·6246	6·3276
10	7·0307	7·7338	8·4368	9·1399	9·8430	10·5460	11·2491	11·9522	12·6553	13·3583
20	14·0614	14·7645	15·4675	16 1706	16·8737	17·5767	18·2798	18·9829	19·6860	20·3890
30	21·0921	21·7952	22·4982	23·2013	23·9044	24·6074	25·3105	26·0136	26·7166	27·4197
40	28·1228	28·8259	29·5289	30·2320	30·9351	31·6381	32·3412	33·0443	33·7473	34·4504
50	35·1535	35·8566	36·5596	37·2627	37·9658	38·6688	39·3719	40·0750	40·7780	41·4811
60	42·1842	42·8873	43·5903	44·2934	44·9965	45·6995	46·4026	47·1057	47·8087	48·5118
70	49·2149	49·9179	50·621	51·324	52·027	52·730	53·433	54·136	54·839	55·543
80	56·246	56·949	57·652	58·355	59·058	59·761	60·464	61·167	61·870	62·573
90	63·276	63·979	64·682	65·385	66·089	66·792	67·495	68·198	68·901	69·604
100	70·307									

POUNDS TO KILOGRAMS

lb.	0	1	2	3	4	5	6	7	8	9
	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.
—	—	0·45359	0·90718	1·36078	1·81437	2·26796	2·72155	3·17515	3·62874	4·08233
10	4·53592	4·98952	5·4431	5·8967	6 3503	6·8039	7·2575	7·7111	8·1647	8·6183
20	9·0718	9·5254	9·9790	10·4326	10·8862	11·3398	11·7934	12·2470	12·7006	13·1542
30	13·6078	14·0614	14·5150	14·9686	15·4221	15·8757	16·3293	16·7829	17·2365	17·6901
40	18·1437	18·5973	19·0509	19·5045	19·9581	20·4117	20·8653	21·3188	21·7724	22·2260
50	22·6796	23·1332	23·5868	24·0404	24·4940	24·9476	25·4012	25·8548	26·3084	26·7620
60	27·2155	27·6691	28·1227	28·5763	29·0299	29·4835	29 9371	30·3907	30·8443	31·2979
70	31·7515	32·2051	32·6587	33·1122	33·5658	34 0194	34·4730	34·9266	35·3802	35·8338
80	36·2874	36·7410	37·1946	37·6482	38·1018	38·5554	39·0089	39·4625	39·9161	40·3697
90	40·8233	41·2769	41·7305	42·1841	42·6377	43·0913	43·5449	43·9985	44·4521	44·9057
100	45·3592	45·8128	46·2664	46·7200	47·1736	47·6272	48 0808	48·5344	48·9880	49·4416
10	49·8952	50·349	50·802	51·256	51·710	52·163	52·617	53·070	53·524	53·977
20	54·431	54·885	55·338	55·792	56·245	56·699	57·153	57·606	58·060	58·513
30	58·967	59·421	59·874	60·328	60·781	61·235	61 689	62·142	62·596	63·049
40	63·503	63·957	64·410	64·864	65·317	65·771	66·224	66·678	67·132	67·585
50	68·039	68·492	68·946	69·400	69·853	70·307	70·760	71·214	71·668	72·121
60	72·575	73·028	73·482	73·936	74·389	74·843	75·296	75·750	76·204	76·657
70	77·111	77·564	78·018	78·471	78·925	79·379	79·832	80·286	80·739	81·193
80	81·647	82·100	82·554	83·007	83·461	83·915	84·368	84·822	85·275	85·729
90	86·183	86·636	87·090	87·543	97·997	88·451	88·904	89·358	89·811	90·265
200	90·718	91·172	91·626	92·079	92·533	92·986	93·440	93·894	94·347	94·801
10	95·254	95·708	96·162	96·615	97·069	97·522	97·976	98·430	98·883	99 337
20	99·790	100·244	100·698	101·151	101·605	102·058	102·512	102·965	103·419	103·873
30	104·326	104·780	105·233	105·687	106·141	106·594	107·048	107·501	107·955	108·409
40	108·862	109·316	109·769	110·223	110·677	111·130	111·584	112·037	112·491	112·945
50	113·398	113·852	114·305	114·759	115·212	115·666	116·120	116·573	117·027	117·480
60	117·934	118·388	118·841	119·295	119·748	120·202	120·656	121·109	121·563	122·016
70	122·470	122·924	123·377	123·831	124·284	124·738	125·192	125·645	126·099	126·552
80	127·006	127·459	127·913	128·367	128·820	129·274	129·727	130·181	130·635	131·088
90	131·542	131·995	132·449	132·903	133·356	133·810	134·263	134·717	135·171	135·624
300	136·078	136·531	136·985	137·439	137·892	138·346	138·799	139·253	139·706	140·160
10	140·614	141·067	141·521	141·974	142·428	142·882	143·335	143·789	144·242	144·696
20	145·150	145·603	146·057	146·510	146·964	147·418	147·871	148·325	148·778	149 232
30	149·686	150·139	150·593	151·046	151·500	151·953	152·407	152·861	153·314	153·768
40	154·221	154·675	155·129	155·582	156·036	156·489	156·943	157·397	157·850	158·304
50	158·757	159·211	159·665	160·118	160·572	161·025	161·479	161·932	162·386	162·840
60	163·293	163·747	164·200	164·654	165·108	165·561	166 015	166·468	166·922	167·376
70	167·829	168·283	168·736	169·190	169·644	170·097	170·551	171·004	171·458	171·912
80	172·365	172·819	173·272	173·726	174·179	174·633	175·087	175·540	175·994	176 447
90	176·901	177·355	177·808	178·262	178·715	179·169	179 623	180·076	180·530	180·983
400	181·437	181·891	182·344	182·798	183·251	183·705	184·159	184·612	185·066	185·519
10	185·975	186·426	186·880	187·334	187·787	188·241	188 694	189·148	189·602	190·056
20	190·509	190·962	191·416	191·870	192·323	192·777	193·230	193·684	194·138	194·591
30	195·045	195·498	195·952	196·406	196·859	197·313	197·766	198·220	198·673	199·127
40	199·581	200·034	200·488	200·941	201·395	201·849	202·302	202·756	203·209	203·663
50	204·117	204·570	205·024	205·477	205·931	206·385	206·838	207·292	207·745	208·199
60	208·653	209·106	209·560	210·013	210·467	210·920	211·374	211·828	212·281	212·735
70	213·188	213·642	214·096	214·549	215·003	215·456	215·910	216·364	216·817	217·271
80	217·724	218·178	218·632	219·085	219·539	219·992	220·446	220·900	221·353	221·807
90	222·260	222·714	223·167	223·621	224·075	224 528	224·982	225·435	225·889	226·343

KILOGRAMS TO POUNDS

Kg.	0	1	2	3	4	5	6	7	8	9
	lb.	lb.	lb.	lb.	lb	lb	lb.	lb.	lb.	lb.
—	—	2·20462	4 40924	6 6139	8 8185	11 0231	13 2277	15·4324	17·6370	19·8416
10	22·0462	24·2508	26·4555	28·6601	30 8647	33 0693	35 2740	37·4786	39 6832	41·8878
20	44·0924	46·2971	48 5017	50 706	52 911	55 116	57·320	59 525	61·729	63·934
30	66·139	68·343	70 548	72 753	74 957	77·162	79 366	81 571	83·776	85·980
40	88·185	90·390	92 594	94·799	97 003	99 208	101 413	103 617	105·822	108·026
50	110·231	112·436	114·640	116 845	119 050	121 254	123·459	125 663	127·868	130·073
60	132·277	134·482	136·687	138 891	141 096	143 300	145 505	147·710	149·914	152·119
70	154·324	156·528	158 733	160·937	163 142	165 347	167·551	169·756	171·961	174·165
80	176·370	178·574	180 779	182 984	185·188	187 393	189·598	191 802	194·007	196·211
90	198·416	200·621	202·825	205 030	207·235	209 439	211 644	213 848	216·053	218·258
100	220·462	222·667	224·871	227·076	229·281	231·485	233·690	235 895	238·099	240·304
10	242·508	244·713	246·918	249·122	251·327	253 532	255·736	257·941	260·145	262·350
20	264·555	266·759	268·964	271·169	273·373	275·578	277·782	279·987	282·192	284·396
30	286·601	288·806	291·010	293·215	295·419	297·624	299·829	302 033	304·238	306·442
40	308·647	310·852	313 056	315·261	317 466	319 670	321·875	324·079	326·284	328·489
50	330·693	332·898	335·103	337·307	339·512	341·716	343·921	346·126	348·330	350·535
60	352·740	354·944	357·149	359·353	361·558	363 763	365·967	368·172	370·377	372·581
70	374·786	376·990	379·195	381·400	383·604	385·809	388·014	390·218	392·423	394·627
80	396·832	399·037	401·241	403·446	405·651	407 855	410·060	412·264	414·469	416·674
90	418·878	421·083	423·288	425·492	427·697	429·901	432·106	434·311	436·515	438·720
200	440·924	443·129	445·334	447 538	449·743	451 948	454·152	456·357	458·561	460·766
10	462·971	465·175	467·380	469·585	471·789	473·994	476·198	478·403	480·608	482·812
20	485·017	487·222	489·426	491·631	493·835	496·040	498 245	500·45	502·65	504·86
30	507·06	509·27	511·47	513·68	515 88	518·09	520·29	522·50	524 70	526·90
40	529·11	531·31	533 52	535·72	537·93	540·13	542·34	544·54	546·75	548·95
50	551·16	553·36	555·56	557·77	559·97	562·18	564·38	566·59	568·79	571·00
60	573·20	575·41	577·61	579·82	582·02	584·22	586 43	588·63	590·84	593·04
70	595·25	597·45	599·66	601·86	604·07	606·27	608·48	610 68	612·89	615·09
80	617·29	619·50	621·70	623·91	626·11	628·32	630·52	632 73	634·93	637·14
90	639·34	641·55	643·75	645·95	648·16	650 36	652·57	654·77	656·98	659·18
300	661·39	663·59	665·80	668·00	670 21	672·41	674·61	676·82	679·02	681·23
10	683·43	685·64	687·84	690·05	692·26	694·46	696·66	698·87	701·07	703·27
20	705·48	707·68	709·89	712·09	714·30	716·50	718·71	720·91	723·12	725·32
30	727·53	729·73	731·93	734·14	736·34	738·55	740·75	742·96	745·16	747·37
40	749·57	751·78	753·98	756·19	758·39	760·59	762·80	765·00	767 21	769·41
50	771·62	773·82	776·03	778·23	780·44	782·64	784·85	787·05	789·25	791 46
60	793·66	795·87	798·07	800·28	802·48	804·69	806·89	809·10	811 30	813 51
70	815·71	817·91	820·12	822·32	824·53	826·73	828·94	831·14	833·35	835 55
80	837·76	839·96	842·17	844·37	846·57	848·78	850·98	853·19	855 39	857·60
90	859·80	862·01	864·21	866·42	868·62	870·83	873·03	875·24	877·44	879·64
400	881·85	884·05	886·26	888·46	890·67	892·87	895·08	897·28	899·49	901 69
10	903·90	906·10	908·30	910·51	912·71	914·92	917 12	919·33	921·53	923·74
20	925·94	928·15	930·35	932·56	934·76	936·96	939·17	941 37	943·58	945·78
30	947·99	950·19	952·40	954·60	956·81	959·01	961 22	963 42	965·62	967·83
40	970·03	972·24	974·44	976·65	978·85	981·06	983·26	985·47	987 67	989·88
50	992·08	994·28	996·49	998·69	1000·90	1003·10	1005·31	1007·51	1009·72	1011·92
60	1014·13	1016·33	1018·54	1020·74	1022·94	1025·15	1027 35	1029·56	1031 76	1033·97
70	1036·17	1038·38	1040·58	1042·79	1044·99	1047·20	1049·40	1051·60	1053·81	1056·01
80	1058·22	1060·42	1062·63	1064·83	1067·04	1069·24	1071·45	1073·65	1075·86	1078 06
90	1080·26	1082·47	1084·67	1086·88	1089·08	1091·29	1093·49	1095·70	1097·90	1100·11

MILLIMETRES TO INCHES

Millimetres	Inches	Millimetres	Inches	Millimetres	Inches	Millimetres	Inches
1	0·0394	57	2·2441	113	4·4489	169	6·6537
2	0·0787	58	2·2835	114	4·4883	170	6·6930
3	0·1181	59	2·3229	115	4·5276	171	6·7324
4	0·1575	60	2·3622	116	4·5670	172	6·7718
5	0·1969	61	2·4016	117	4·6064	173	6·8111
6	0·2362	62	2·4410	118	4·6458	174	6·8505
7	0·2756	63	2·4804	119	4·6851	175	6·8899
8	0·3150	64	2·5197	120	4·7245	176	6·9293
9	0·3543	65	2·5591	121	4·7639	177	6·9686
10	0·3937	66	2·5985	122	4·8032	178	7·0080
11	0·4331	67	2·6378	123	4·8426	179	7·0474
12	0·4724	68	2·6772	124	4·8820	180	7·0867
13	0·5118	69	2·7166	125	4·9213	181	7·1261
14	0.5512	70	2·7560	126	4·9607	182	7·1655
15	0·5906	71	2·7953	127	5·0000	183	7·2049
16	0·6299	72	2·8347	128	5·0394	184	7·2442
17	0·6693	73	2·8741	129	5·0788	185	7·2836
18	0·7087	74	2·9134	130	5·1182	186	7·3230
19	0·7480	75	2·9528	131	5·1576	187	7·3623
20	0·7874	76	2·9922	132	5·1969	188	7·4017
21	0·8268	77	3·0316	133	5·2363	189	7·4411
22	0·8662	78	3·0709	134	5·2757	190	7·4805
23	0·9055	79	3·1103	135	5·3151	191	7·5198
24	0·9449	80	3·1497	136	5·3544	192	7·5592
25	0·9843	81	3·1890	137	5·3938	193	7·5986
26	1·0236	82	3·2284	138	5·4332	194	7·6379
27	1·0630	83	3·2678	139	5·4725	195	7·6773
28	1·1024	84	3·3071	140	5·5119	196	7·7167
29	1·1418	85	3·3465	141	5 5513	197	7·7560
30	1·1811	86	3·3859	142	5·5907	198	7·7954
31	1·2205	87	3·4253	143	5·6300	199	7·8348
32	1·2599	88	3·4646	144	5·6694	200	7·8742
33	1·2992	89	3·5040	145	5·7088	201	7·9135
34	1·3386	90	3·5434	146	5·7481	202	7·9529
35	1·3780	91	3·5827	147	5·7875	203	7·9923
36	1·4173	92	3·6221	148	5·8269	204	8·0316
37	1·4567	93	3·6615	149	5·8662	205	8·0710
38	1·4961	94	3·7009	150	5·9056	206	8·1104
39	1·5355	95	3·7402	151	5·9450	207	8·1498
40	1·5748	96	3·7796	152	5·9844	208	8·1891
41	1·6142	97	3·8190	153	6·0237	209	8·2285
42	1·6536	98	3·8583	154	6·0631	210	8·2679
43	1·6929	99	3·8977	155	6·1025	211	8·3072
44	1·7323	100	3·9371	156	6·1418	212	8·3466
45	1·7717	101	3·9764	157	6·1812	213	8·3860
46	1·8111	102	4·0158	158	6·2206	214	8·4253
47	1·8504	103	4·0552	159	6 2600	215	8·4647
48	1·8898	104	4·0946	160	6·2993	216	8·5041
49	1·9292	105	4·1339	161	6·3387	217	8·5435
50	1·9685	106	4·1733	162	6·3781	218	8·5828
51	2·0079	107	4·2127	163	6·4174	219	8·6222
52	2·0473	108	4·2520	164	6·4568	220	8·6616
53	2·0867	109	4·2914	165	6·4962	221	8·7009
54	2·1260	110	4·3308	166	6·5356	222	8·7403
55	2·1654	111	4·3702	167	6·5749	223	8·7797
56	2·2048	112	4·4095	168	6·6143	224	8·8191

INCHES AND DECIMAL EQUIVALENTS TO MILLIMETRES

In.	In.	Mm.	In.	In.	Mm.
1/64 =	0·015625 =	·39688	33/64 =	0·515625 =	13·09690
1/32 =	0·03125 =	·79375	17/32 =	0·53125 =	13·49378
3/64 =	0·046875 =	1·19063	35/64 =	0·546875 =	13·89065
1/16 =	0·0625 =	1·58750	9/16 =	0·5625 =	14·28753
5/64 =	0·078125 =	1·98438	37/64 =	0·578125 =	14·68440
3/32 =	0·09375 =	2·38125	19/32 =	0·59375 =	15·08128
7/64 =	0·109375 =	2·77813	39/64 =	0·609375 =	15·47816
1/8 =	0·125 =	3·17501	5/8 =	0·625 =	15·87503
9/64 =	0·140625 =	3·57188	41/64 =	0·640625 =	16·27191
5/32 =	0·15625 =	3·96876	21/32 =	0·65625 =	16·66878
11/64 =	0·171875 =	4·36563	43/64 =	0·671875 =	17·06566
3/16 =	0·1875 =	4·76251	11/16 =	0·6875 =	17·46254
13/64 =	0·203125 =	5·15939	45/64 =	0·703125 =	17·85941
7/32 =	0·21875 =	5·55626	23/32 =	0·71875 =	18·25629
15/64 =	0·234375 =	5·95314	47/64 =	0·734375 =	18·65316
1/4 =	0·25 =	6·35001	3/4 =	0·75 =	19·05004
17/64 =	0·265625 =	6·74689	49/64 =	0·765625 =	19·44691
9/32 =	0·28125 =	7·14376	25/32 =	0·78125 =	19·84379
19/64 =	0·296875 =	7·54064	51/64 =	0·796875 =	20·24067
5/16 =	0·3125 =	7·93752	13/16 =	0·8125 =	20·63754
21/64 =	0·328125 =	8·33439	53/64 =	0·828125 =	21·03442
11/32 =	0·34375 =	8·73127	27/32 =	0·84375 =	21·43129
23/64 =	0·359375 =	9·12814	55/64 =	0·859375 =	21·82817
3/8 =	0·375 =	9·52502	7/8 =	0·875 =	22·22504
25/64 =	0·390625 =	9·92190	57/64 =	0·890625 =	22·62192
13/32 =	0·40625 =	10·31877	29/32 =	0·90625 =	23·01880
27/64 =	0·421875 =	10·71565	59/64 =	0·921875 =	23·41567
7/16 =	0·4375 =	11·11252	15/16 =	0·9375 =	23·81255
29/64 =	0·453125 =	11·50940	61/64 =	0·953125 =	24·20942
15/32 =	0·46875 =	11·90627	31/32 =	0·96875 =	24·60630
31/64 =	0·484375 =	12·30315	63/64 =	0·984375 =	25·00318
1/2 =	0·5 =	12·70005	1 =	1·0 =	25·40010

WEIGHTS OF STEEL FLATS

In Lbs. per Foot run

Thickness

Width	1/8 in.	1/4 in.	3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.
In.								
1/8	—	—	—	—	—	—	—	—
1/4	·10	·21	—	—	—	—	—	—
3/8	·16	·32	·47	—	—	—	—	—
1/2	·21	·43	·64	·85	—	—	—	—
5/8	·27	·53	·80	1·07	1·32	—	—	—
3/4	·32	·64	·96	1·28	1·60	1·91	—	—
7/8	·37	·75	1·12	1·49	1·87	2·24	2·60	—
1	·43	·85	1·28	1·70	2·13	2·55	2·98	3·40
1 1/8	·48	·96	1·43	1·91	2·39	2·87	3·35	3·83
1 1/4	·53	1·06	1·59	2·13	2·66	3·19	3·72	4·25
1 3/8	·58	1·17	1·75	2·34	2·92	3·51	4·09	4·68
1 1/2	·64	1·28	1·91	2·55	3·19	3·83	4·46	5·10
1 5/8	·69	1·38	2·07	2·76	3·45	4·14	4·83	5·55
1 3/4	·75	1·49	2·23	2·98	3·72	4·46	5·21	5·97
1 7/8	·80	1·60	2·40	3·20	4·00	4·80	5·60	6·40
2	·85	1·71	2·56	3·41	4·27	5·12	5·97	6·82
2 1/8	·91	1·81	2·72	3·63	4·53	5·44	6·35	7·25
2 1/4	·96	1·92	2·88	3·84	4·80	5·76	6·72	7·68
2 3/8	1·01	2·03	3·04	4·05	5·07	6·08	7·09	8·09
2 1/2	1·07	2·13	3·20	4·27	5·33	6·40	7·47	8·53
2 5/8	1·12	2·24	3·36	4·48	5·60	6·72	7·84	8·96
2 3/4	1·17	2·35	3·52	4·69	5·87	7·04	8·21	9·39
2 7/8	1·23	2·45	3·68	4·91	6·13	7·36	8·59	9·81
3	1·28	2·56	3·84	5·12	6·40	7·68	8·96	10·24
3 1/8	1·33	2·66	4·00	5·33	6·67	8·00	9·33	10·67
3 1/4	1·39	2·77	4·16	5·55	6·93	8·32	9·71	11·09
3 3/8	1·44	2·88	4·32	5·76	7·20	8·64	10·08	11·52
3 1/2	1·49	2·99	4·48	5·97	7·47	8·96	10·45	11·95
3 3/4	1·60	3·20	4·80	6·40	8·00	9·60	11·20	12·80
3 7/8	1·65	3·31	4·96	6·61	8·27	9·92	11·57	13·23
4	1·71	3·41	5·12	6·83	8·53	10·24	11·95	13·65
4 1/8	1·76	3·52	5·28	7·04	8·80	10·56	12·32	14·08
4 1/4	1·81	3·63	5·44	7·25	9·07	10·88	12·69	14·51
4 3/8	1·87	3·73	5·60	7·47	9·33	11·20	13·07	14·93
4 1/2	1·92	3·84	5·76	7·68	9·60	11·52	13·44	15·36
4 5/8	1·97	3·95	5·92	7·89	9·87	11·84	13·81	15·79
4 3/4	2·03	4·05	6·08	8·11	10·13	12·16	14·19	16·21
4 7/8	2·08	4·16	6·24	8·32	10·40	12·48	14·56	16·64
5	2·13	4·27	6·40	8·53	10·67	12·80	14·93	17·07
5 1/8	2·19	4·37	6·56	8·75	10·93	13·12	15·31	17·49
5 1/4	2·24	4·48	6·72	8·96	11·20	13·44	15·68	17·92
5 3/8	2·29	4·59	6·88	9·17	11·47	13·76	16·05	18·35
5 1/2	2·35	4·69	7·04	9·39	11·73	14·08	16·43	18·77
5 5/8	2·40	4·80	7·20	9·60	12·00	14·40	16·80	19·20
5 3/4	2·45	4·91	7·36	9·81	12·27	14·72	17·17	19·63
5 7/8	2·51	5·01	7·52	10·03	12·53	15·04	17·55	20·05
6	2·56	5·12	7·68	10·24	12·80	15·36	17·92	20·48
6 1/8	2·61	5·23	7·84	10·45	13·07	15·68	18·29	20·91
6 1/4	2·67	5·33	8·00	10·67	13·33	16·00	18·67	21·33

WEIGHTS OF STEEL BARS

Rounds, Squares, Octagons and Hexagons in Lbs per Linear Foot

Size in Inches	Rounds Lbs./ft.	Squares Lbs./ft.	Hexagons Lbs./ft.	Octagons Lbs./ft.
3/16	·094	·120	·104	·099
1/4	·167	·212	·184	·176
5/16	·261	·332	·288	·275
3/8	·376	·478	·414	·396
7/16	·511	·651	·564	·539
1/2	·668	·850	·736	·704
9/16	·845	1·076	·931	·892
5/8	1·043	1·328	1·150	1·101
11/16	1·262	1·607	1·391	1·332
3/4	1·502	1·913	1·656	1·586
13/16	1·763	2·245	1·943	1·861
7/8	2·044	2·603	2·254	2·158
15/16	2·347	2·988	2·586	2·478
1	2·670	3·400	2·943	2·819
1 1/8	3·380	4·303	3·725	3·568
1 1/4	4·172	5·313	4·598	4·405
1 3/8	5·049	6·428	5·565	5·320
1 1/2	6·008	7·650	6·624	6·343
1 5/8	7·051	8·978	7·772	7·444
1 3/4	8·178	10·41	9·013	8·633
1 7/8	9·388	11·95	10·047	9·910
2	10·68	13·60	11·774	11·276
2 1/8	12·06	15·35	13·305	12·712
2 1/4	13·52	17·21	14·904	14·271
2 3/8	15·06	19·18	16·608	15·885
2 1/2	16·69	21·25	18·396	17·618
2 5/8	18·40	23·43	20·282	19·410
2 3/4	20·19	25·71	22·257	21·318
2 7/8	22·07	28·10	24·330	23·28
3	24·03	30·60	26·496	25·35
3 1/4	28·21	35·92	31·104	29·75
3 1/2	32·71	41·65	36·057	34·50
3 3/4	37·55	47·82	41·396	39·60
4	42·73	54·40	47·099	45·06
4 1/4	48·24	61·41	53·170	50·87
4 1/2	54·07	68·85	59·605	57·01
4 3/4	60·25	76·71	66·412	63·53
5	66·76	85·00	73·590	70·39
5 1/4	73·60	93·71	81·130	77·59
5 1/2	80·78	102·9	89·07	85·17
5 3/4	88·29	112·4	97·32	93·08
6	96·13	122·4	105·87	101·35

For standard High Speed Steel add 12 per cent.

APPENDIX II

WEIGHTS AND MEASURES

WEIGHTS AND MEASURES

1 Acre:
= 10 square chains
= 4840 square yards
= 4 roods
= 160 square rods, poles or perches
= 0·405 hectare
= 4046·86 square metres

Apothecaries' Fluid Measure:

60 minims (drops)	=	1 fluid drachm
8 drachms	=	1 ounce
20 ounces	=	1 pint
8 pints	=	1 gallon

Apothecaries' Weight:

1 scruple	= 20 grains		
1 drachm	= 3 scruples	= 60 grains	
1 ounce	= 8 drachms	= 480 grains	
1 pound	= 12 ounces	= 5760 grains	

1 Are:
= 100 square metres
= 0·01 hectare

1 Barrel (U.S.A.):
= 9702 cubic inches
= 5·6146 cubic feet
= 0·15899 cubic metre
= 158·984 litres
= 34·9726 gallons (Imperial)
= 42·00 gallons (U.S.A.)

1 Bushel:
= 4 pecks
= 8 gallons (Imperial)
= 9·6076 gallons (U.S.A.)
= 0·25 quarter
= 0·03637 cubic metre
= 0·04757 cubic yard

1 Cable Length:
= 240 yards
= 219·456 metres
= 120 fathoms

1 Carat (Metric):
= 200 milligrams
= 3·0865 grains

1 Cental:
= 100 pounds

1 Centigram:
= 0·01 gram
= 0·15 grain

1 Centilitre:
= 10 millilitres
= 0·10 decilitre

1 Centimetre (cm.):
= 0·03281 foot
= 0·3937011 inch (Imperial)
= 0·3937008 inch (U.S.A.)
= 0·01 metre
= 10 millimetres

1 Chain:
= 22 yards
= 100 links
= 4 rods
= 0·1 furlong
= 20·117 metres

Cheval Vapeur (C.V.). (See *Pferdestärke.*)

1 Circular Inch:
= 5·0671 square centimetres
= 0·7854 square inch

1 Coomb:
= 4 bushels

1 Cubic Centimetre (ccm., cm ^{3}):
= 0·061024 cubic inch
= 1000 cubic millimetres

1 Cubic Foot (cu. ft.):
= 0·17811 barrel (U.S.A.)
= 1728·00 cubic inches
= 0·037037 cubic yard
= 49·831 pints
= 6·2288 gallons, fluid (Imperial)
= 6·429 gallons, dry (U.S.A.)
= 7·4805 gallons, fluid (U.S.A.)
= 0·0283169 cubic metre
= 28·3168 litres

1 Cubic Inch (cu. in.):
= 16·387 cubic centimetres
= 0·0005787 cubic foot
= 0·01639 litre
= 0·0288 pint (Imperial)
= 0·01732 quart, fluid (U.S.A.)

1 Cubic Metre (m ^{3}):
= 6·2898 barrels (U.S.A.)
= 61,024 cubic inches
= 35·3147 cubic feet
= 1·30794 cubic yards
= 1000 cubic decimetres
= 219·969 gallons (Imperial)

1 Cubic Yard (cu. yd.):
= 46,656 cubic inches
= 27 cubic feet
= 0·76455 cubic metres
= 764·56 litres
= 1615·79 pints (U.S.A.)
= 168·178 gallons, fluid (Imperial)
= 201·974 gallons, fluid (U.S.A.)

1 Decigram:
= 0·1 gram

1 Decilitre:
= 0·1 litre
= 0·17598 pint (Imperial)
= 0·21134 pint (U.S.A.)

1 Decimetre:
= 3·937 inches
= 0·10936 yard
= 0·1 metre

1 Dekagram:
= 10 grams

1 Dekalitre:
= 10 litres

1 Dekametre:
= 10 metres

1 Drachm (Fluid.):
= 0·125 fluid ounce
= 3·552 cubic centimetres

1 Drachm (Apoth):
= 60 grains
= 0·125 ounce (troy)
= 0·137 ounce (av.)
= 3·888 grams

Dram. (See *Drachm.*)

1 Ell:
= 1·25 yards
= 45 inches

1 Fathom:
= 6 feet
= 1·829 metres
= 0·0083 cable length

1 Foot (ft.):
= 12 inches
= 0·3333 yard
= 304·7997 millimetres

1 Furlong:
= 0·125 mile
= 10 chains
= 40 rods
= 201·168 metres

1 Gallon, Liquid (Imperial) (gal.):
= 0·028594 barrel (U.S.A.)
= 160 ounces, fluid
= 8 pints
= 1·20095 gallons, liquid (U.S.A.)
= 277·420 cubic inches
= 0·1605 cubic foot
= 0·004546 cubic metre
= 4·5459631 litres

1 Gallon, Liquid (U.S.A.) (gal.):
= 0·0238095 barrel (U.S.A.)
= 128 ounces, fluid (U.S.A.)
= 0·83267 gallon, liquid (Imperial)
= 231 cubic inches
= 0·13368 cubic foot
= 3785·3 cubic centimetres
= 3·7853 litres

1 Gill:
= 0·25 pint
= 8·669 cubic inches
= 142·07 cubic centimetres
= 5 ounces, fluid

1 Grain:
= 0·0167 drachm (Apoth.)
= 0·0023 ounce (av.)
= 0·0021 ounce (tr.)
= 0·0648 gram

1 Gram (g.):
= 0·001 kilogram
= 0·035274 ounce (av.)
= 0·032151 ounce (tr.)
= 0·0022046 pound
= 15·432 grains

1 Gross:
= 12 dozen

Gross Ton. (See *Long Ton.*)

1 Hand:
= 4 inches

1 Hectare:
= 100 ares
= 2·471 acres
= 9·884 roods
= 395·369 square rods
= 10,000 square metres
= 11,959·9 square yards

1 Hectogram:
= 10 dekagrams
= 0·1 kilogram

1 Hectolitre:
= 10 dekalitres
= 0·1 kilolitre

1 Hectometre:
= 100 metres
= 109·361 yards

1 Horse Power (h.p.):
= 2544·99 B.Th.U. per hour
= 550 foot pounds per second
= 0·7457 kilowatt
= 76·043 metrekilograms per second
= 1·0139 pferdestärken

1 Hundredweight (Imperial) (cwt.):
= 50·80238 kilograms
= 112 pounds
= 4 quarters (28 pounds each)

1 Hundredweight (U.S.A.) (cwt.):
= 45·36 kilograms
= 100 pounds
= 4 quarters (25 pounds each)

1 Inch (in.)
= 0·08333 foot
= 25·399956 millimetre (exact)
= 0·0254 metre

1 Kilogram (kg.):
= 0·01968 hundredweight (Imperial)
= 0·02205 hundredweight (U.S.A.)
= 35·27396 ounces (av.)
= 2·20462 pounds (av.)
= 2·67922 pounds (tr.)
= 0·01 quintal
= 0·001102 ton (of 2000 pounds)
= 0·0009842 ton (of 2240 pounds)
= 0·001 ton (metric)

1 Kilolitre:
= 1000 litres

1 Kilometre:
= 1000 metres
= 0·621 mile

1 Last:
= 10 quarters

1 Link:
= 7·92 inches
= 0·01 chain
= 0·22 yard
= 0·2012 metre

1 Litre:
= 61·024 cubic inches
= 0·03531 cubic foot
= 1·75980 pints (Imperial)
= 2·11337 pints (U.S.A.)
= 0·88 quart, liquid (Imperial)
= 1·0567 quarts, liquid (U.S.A.)
= 0·219975 gallon, liquid (Imperial)
= 0·2642 gallon, liquid (U.S.A.)
= 0·00629 barrel (U.S.A.)
= 1000·03 cubic centimetres

1 Load:
= 5 quarters

Long Ton. (See *Ton.*)

1 Metre (m.):
= 39·3700 inches
= 3·28084 feet
= 1·093614 yards
= 0·04971 chain
= 0·198839 rod

Metric Ton. (See *Ton.*)

1 Micron:
= 0·001 millimetre

1 Mil:
= 0·001 inch

1 Mile:
= 1760 yards
= 1·609 kilometres

1 Mile (Nautical):
= 1·1515 miles
= 6080 feet
= 1853·18 metres

1 Milligram:
= 0·001 gram
= 0·015432 grain
= 0·005 metric carat

1 Millilitre:
= 0·061025 cubic inch

1 Millimetre (mm.):
= 10 ångström
= 0·03937011 inch (Imperial)
= 0·03937008 inch (U.S.A.)
= 1000 micron

Minim. (See *Apothecary.*)

1 Nail:
= 2·25 inches

1 Ounce (*av.*) (oz.):
= 0·0625 pound
= 437·5 grains
= 0·9115 ounce (tr.)
= 7·292 drachms (Apoth.)
= 28·349 grams

1 Peck:
= 2 gallons (Imperial)
= 0·25 bushel

1 Pennyweight (dwt.):
= 24 grains
= 0·05 ounce (tr.)

Perch. (See *Rod.*)

1 Pferdestärke (*Cheval Vapeur*):
= 0·0977 B.Th.U. per second
= 542·5 foot pounds per second
0·9863 horse power
= 0·7355 kilowatt

1 Pint (Imperial):
= 0·125 gallon (Imperial)
= 0·568 litre

1 Pint (U.S.A.):
= 0·125 gallon (U.S.A.)
= 0·4732 litre

Pole. (See *Rod.*)

1 Pottle:
= 2 quarts

1 Pound (*av.*) (lb.):
= 1·21528 pounds (tr.)
= 7000 grains
= 16 ounces
= 0·008 hundredweight
= 453·592428 grams

1 Pound (*tr.*):
= 0·82286 pound (av.)
= 5760 grains
= 373·242 grams

1 Quart:
= 8 gills
= 2 pints
= 0·25 gallon (Imperial)
= 1·1365 litres
= 0·040 cubic foot

1 Quarter (qtr.):
= 28 pounds (av.)
= 34·028 pounds (tr.)
= 8 bushels
= 12·701 kilograms

1 Quintal:
= 100 kilograms
= 220·5 pounds

1 Quire (Paper):
= 24 sheets

1 Ream (Paper):
= 20 quires

1 Rod, Pole or *Perch:*
= 5·5 yards
= 0·25 chain
= 0·025 furlong
= 0.003 mile
= 5·029 metres

1 Rood:
= 0·25 acre
= 1210 square yards
= 1011·71 square metres

Scruple. (See *Apothecary.*)

1 Shipping Ton (Imperial):
= 42 cubic feet (Timber)
= 1·1894 cubic metres

1 Shipping Ton (U.S.A.):
= 40 cubic feet (Merchandise)
= 1·1328 cubic metres

Short Ton (See *Ton.*)

1 Square Centimetre (cm.²):
0·0001 square metre
= 100 square millimetres
= 0·15500 square inch
= 0·001076 square foot

1 Square Foot (sq. ft.):
= 144 square inches
= 0·1111 square yard
= 0·0929 square metre

1 Square Inch (sq. in.):
= 0·00694 square foot
= 0·00077 square yard
= 645·15898 square millimetres
= 6·4515898 square centimetres

1 Square Kilometre (km ²):
= 0·386 square mile
100 hectares

1 Square Metre (m.²):
= 1550 square inches
= 10·76387 square feet
= 1·1960 square yards

1 Square Mile:
= 640 acres
= 2·590 square kilometres

1 Square Millimetre (mm.²):
= 0·01 square centimetre
= 0·0015 square inch

1 Square Rod:
= 30·25 square yards
= 25·293 square metres
= 0·025 roods

1 Square Yard (sq. yd.):
9 square feet
= 0·836 square metre

1 Stone:
14 pounds (av.)
6·35 kilograms

1 Ton (Long Ton, 2240 pounds) (t.):
= 1016·0475 kilograms
2240 pounds
80 quarters
20 hundredweights
= 1·016 metric tons
= 1·12 short tons

1 Ton (Metric or Metre Ton):
1000 kilograms
0·98421 long ton

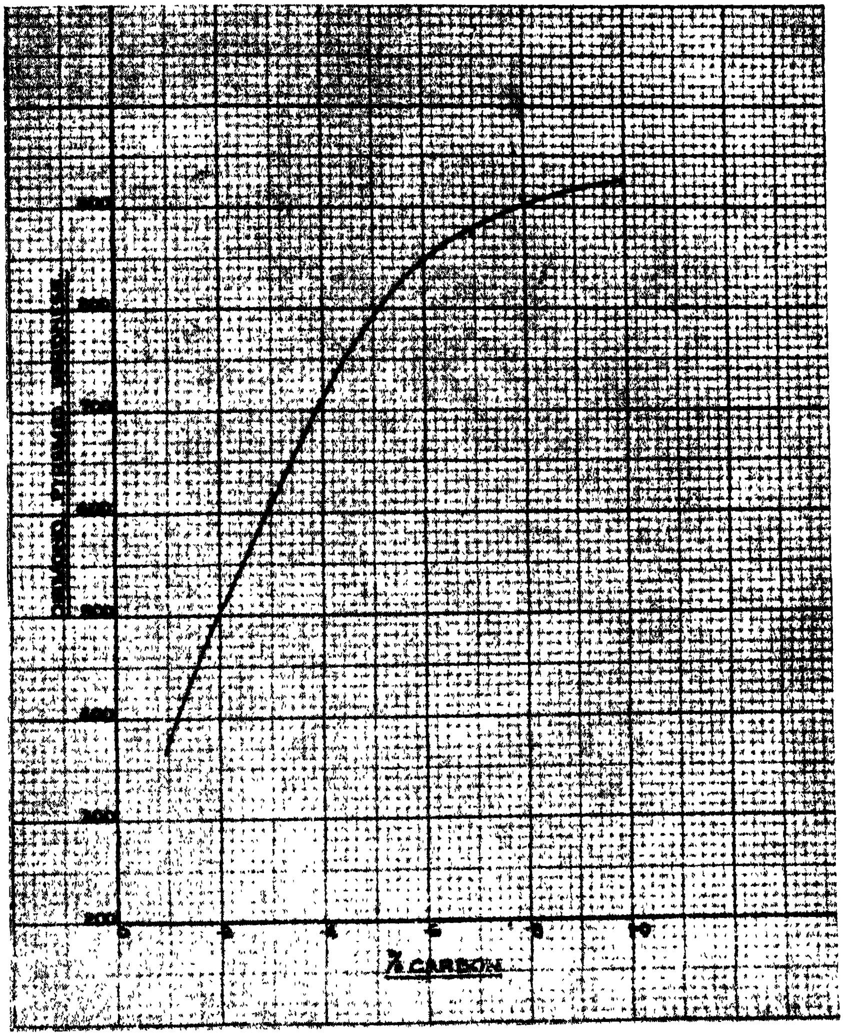
1 Ton (Short Ton, 2000 pounds) (t):
907·1848 kilograms
2000 pounds
17·857 hundredweights
0·89286 long ton
0·9072 tonne

1 Yard (yd.):
36 inches
3 feet
0·9144018 metre

APPENDIX III

PROPERTIES (a-d)

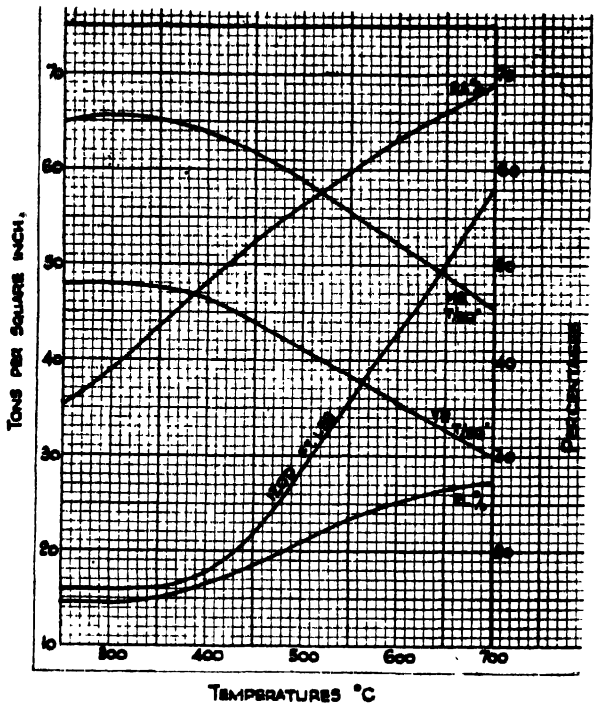
EFFECT OF CARBON ON HARDNESS OF PLAIN CARBON STEEL



EFFECT OF TEMPERING

(i) Plain carbon steel

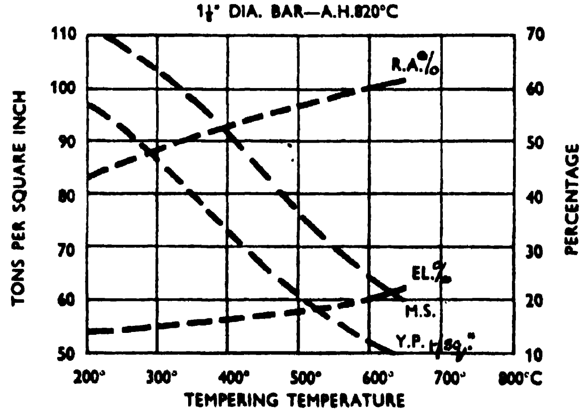
(C ·45, Si ·15, Mn ·50%)



(ii) **Alloy steel**

(C. ·30, Ni 4·25, Cr 1·25%)

1⅛" DIA. BAR—A.H.820°C

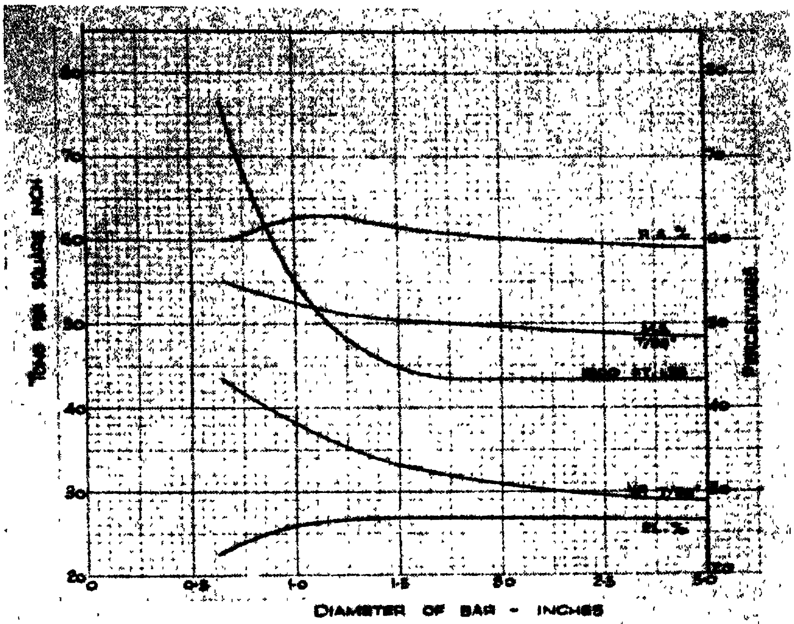


APPENDIX III (d)

EFFECT OF MASS

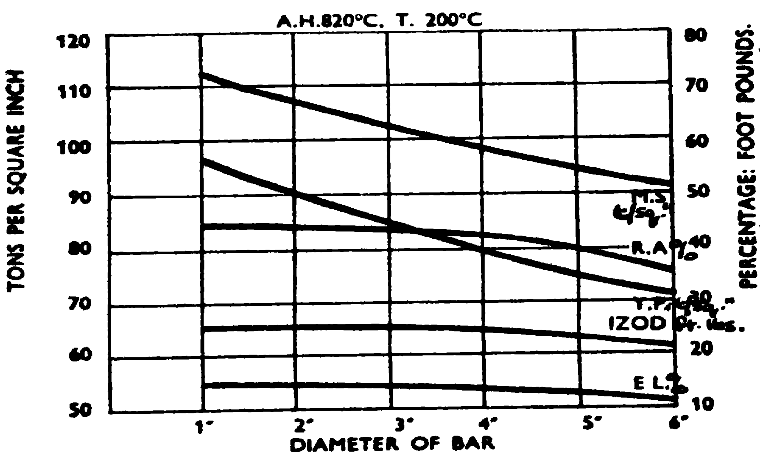
(i) Plain carbon steel

(C ·45, Si ·15, Mn ·50%)



(ii) Alloy steel

(C ·30, Ni 4·25, Cr 1·25%)



APPENDIX IV

SIGNS AND SYMBOLS

SIGNS AND SYMBOLS

$+$	Plus; positive.
$-$	Minus; negative.
$\pm$	Plus or minus; positive or negative.
$\times$ $(\cdot)$	Multiplied by.
$\cdot$ $(\times)$	Multiplied by.
$\div$ $(:)$	Divided by.
$:$ $(\div)$	Divided by.
$/$	Divided by.
$=$	Equals.
$::$ $(=)$	Is equal to; as.
$:$	Ratio.
$\fallingdotseq$	Is approximately equal to.
$\neq$	Is not equal to.
$\neq$	Is not equal to.
$\doteq$	Is approximately equal to; approaches.
$\hat{=}$	Denotes equivalence in area or volume.
$\cong$	Approximately equal to.
$\approxeq$	Approximately equal to.
$\equiv$	Is identically equal to.
$\not\equiv$ $\not\equiv$	Is not identically equal to.
$\sim$	Is similar to.
$\backsim$	Is similar to.
$>$	Greater than.
$<$	Less than.
$\gg$	So much greater than.
$\ll$	So much less than.
$\geqq$	Equal to or greater than.
$\geq$	Greater than or equal to.
$\leqq$	Equal to or less than.
$\leq$	Less than or equal to.
$\nless$	Not less than.
$\ngtr$	Is not greater than.
$\gtrless$	Is greater than or less than but not equal to.
$\sim$	Denotes a difference between two quantities without designating the greater.

SIGNS AND SYMBOLS (contd.)

$\subset$	Is contained in.
$\not\subset$	Is not contained in.
$\subseteq$	Is contained in or equal to.
$\dashv$	Is a part of.
$\propto$	Varies as; is proportional to.
∞	Infinity; soluble in all proportions.
! (L)	The continued product of numbers from one upward, e.g. $1 \times 2 \times 3 \times 4$.
L (!)	The continued product of numbers from one upwards, e.g. $1 \times 2 \times 3 \times 4$.
$\rightarrow$	Approaches.
$\therefore$	Therefore.
$\because$	Because.
. . . .	And so on.
$^\circ$	Degree (arc or temperature).
$'$	Minute of arc; foot.
$''$	Second of arc; inch.
%	Per hundred; per cent.
‰	Per thousand or 0.1%.
$\sqrt{}$	Square root.
$\sqrt[n]{}$	The n[th] root.
∂	Partial differential.
$\int$	Integral.
$\int_a^b$	Integral between the value b of its variable and its value a.
Δ	Increment.
$\angle$	Angle.
∟	Right angle.
$\perp$	Perpendicular to.
$\parallel$	Parallel to.
○	Circle; circumference; 360°.
⌀	Diameter.
( )	Parentheses.
[ ]	Brackets.
{ }	Braces.
—	Direct current; D.C.
$\sim$	Alternating current; A.C.

APPENDIX V

LIST OF SCIENTIFIC, TECHNICAL AND TRADE SOCIETIES AND OTHER BODIES RELATED TO THE IRON AND STEEL INDUSTRIES

APPENDIX V

LIST OF SCIENTIFIC, TECHNICAL AND TRADE SOCIETIES AND OTHER BODIES RELATED TO THE IRON AND STEEL INDUSTRIES

Academie des Sciences, Quai des Grands-Augustine, 55, Paris, France.

Accidents, Royal Society for the Prevention of. (See *Royal Society for the Prevention of Accidents.*)

Aéronautiques, Office National d'Etudes et de Recherches. (See *Office National d'Etudes et de Recherches Aéronautiques.*)

Aircraft Bolt and Nut Manufacturers' Association, 25, Bennetts Hill, Birmingham.

Alloy Casting Institute, 39, Broadway, New York, 6, N.Y., U.S.A.

Alloy Steel Stockholders' Association, 75, Cannon Street, London, E.C.4. Tel. CITy 1165.

Aluminium Development Association, 33, Grosvenor Street, London, W.1. Tel. MAYfair 7501/8.

Aluminium Industry Council, 60, Calthorpe Road, Edgbaston, Birmingham, 15. Tel. Edgbaston 3805/6.

Amalgamated Society of Wire Drawers and Kindred Workers, Stirling Chambers, Campo Lane, Sheffield, 1. Tel. Sheffield 21674.

American Association for Advancement of Science, 10, McGovern Avenue, Lancaster, Pa., U.S.A.

American Association of Oilwell Drilling Contractors, 321, Reserve Loan Life Building, 505, N. Ervay Street, Dallas 1, Texas, U.S.A.

American Ceramic Society, 2525, N. High Street, Columbus 2, Ohio, U.S.A.

American Chemical Society, 20th and Northampton Streets, Easton, Pa., U.S.A.

American Electroplaters' Society, 473, York Road, Jenkintown, Pa., U.S.A.

American Foundrymen's Society, 616, S. Michigan Avenue, Chicago 5, Ill., U.S.A.

American Gas Association, American Building, Brattleboro, Vt.; or 420, Lexington Avenue, New York 17, N.Y.

American Institute of Chemical Engineers, 15, North Seventh Street, Philadelphia 6, Pa., U.S.A.

American Institute of Chemists, 60, East 42nd Street, New York 17, N.Y., U.S.A.

American Institute of Electrical Engineers, 33, West 39th Street, New York 18, N.Y., U.S.A.

American Institute of Mining and Metallurgical Engineers, 29, West 39th Street, New York 18, N.Y.

American Institute of Physics, Prince and Lenox Streets, Lancaster, Pa.; or 57, East 55th Street, New York 22, N.Y., U.S.A.

American Iron and Steel Institute, 350, Fifth Avenue, New York, N.Y., U.S.A.

American Petroleum Institute, 50, West 50th Street, New York 20, N.Y., U.S.A.

American Railway Engineering Association, 59, East Van Buren Street, Chicago 5, Ill., U.S.A.

American Society for Metals, 7301, Euclid Avenue, Cleveland 3, Ohio, U.S.A.

American Society for Testing Materials, 1916, Race Street, Philadelphia 3, Pa., U.S.A.

American Society of Civil Engineers, 33, West 39th Street, New York 18, N.Y., U.S.A.

American Society of Lubrication Engineers, 343, S. Dearborn Street, Chicago 4, Ill., U.S.A.

American Society of Mechanical Engineers, 29, West 39th Street, New York 18, N.Y., U.S.A.

American Society of Naval Engineers, 605, F. Street, N.W., Washington 4, D.C., U.S.A.

American Society of Tool Engineers, 10,700, Puritan Avenue, Detroit 38, Michigan, U.S.A.

American Standards Association, 70, East 45th Street, New York 17, N.Y., U.S.A.

American Waterworks Association, 521, Fifth Avenue, New York 18, N.Y., U.S.A.

American Welding Society, 33, West 39th Street, New York 18, N.Y., U.S.A.

American Zinc Institute, 60, East 42nd Street, New York 17, N.Y., U.S.A.

Annealing Pot Makers' Association, Bank Buildings, Castle Square, Swansea. Tel. Swansea 4466.

Arts, Royal Society of. (See *Royal Society of Arts.*)